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CORRIGENDA.

Page 546, line 24, for *dynamite* read *dynamic*.

Page 588, line 5, the sentence should read: *A foot-pound is equal to twelve pound-inches, or twelve thousand pound-thousandths-of-an-inch*.

THE PROCEEDINGS

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U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

NAVAL SIGNALING.

By A. P. NIBLACK, Lieutenant, Junior Grade, U. S. Navy.*

It is not proposed to here touch upon the history of signaling, nor to consider the question of interior communication aboard ship, viz., by annunciators, voice tubes, bells, etc. It is the plan to first point out the limitations which affect and control the methods of communication which are available under different conditions, and from a consideration of these to show wherein naval signaling differs in principle from army signaling. We will next take up the consideration of signal codes in use in different military organizations at home and abroad, and from them deduce the theoretical principles which should determine the choice of such codes. This involves a discussion of the concessions which theory must in certain cases,

* Subject to examination.

and for certain good reasons, make to practice as brought out by actual trial in service. The methods of army signaling are touched upon only to illustrate the difference in principle. The different methods of signaling at sea in use in our own and in foreign navies are then taken up and discussed in detail. However meagre the data on which are based the conclusions here set forth, enough is presented to show that there are certain definite principles which must be adhered to in the formation of a code, or the design of any sort of an apparatus or method of transmitting it.

In the navy we have in a measure been dominated by the army. This influence dates back to the Civil War. The Myer signal code was invented by the late Brigadier-General A. J. Myer in 1856, and was first reported on favorably by a board of army officers in 1858. In 1860 Myer was appointed chief signal officer of the army, and ordered West on Indian campaign duty. Many of the officers and men whom he then instructed and organized into a signal corps went South on the breaking out of the Civil War. This resulted in the Myer code being used with conspicuous success on both sides. It was also adopted in the navy, but even in such important operations as those in Mobile Bay we had army signalmen aboard all our ships to receive and transmit messages. It remained the army and navy code until April 3, 1886, when it was unwisely superseded by the Continental Morse, which was in January, 1890, itself more unwisely succeeded by the American Morse code. It was the genius of Myer which first organized and perfected the signal corps of our army, and which first demonstrated the value of rapid and accurate communication in extended operations on shore. Since his death we have gained nothing from the army in the matter of signaling.

In recent years the addition of the duties of the weather bureau to those of the signal corps has done much to overshadow the importance of signaling as an art in itself. Since the Civil War the navy, in squadron cruising, has had daily practice in signaling of all sorts, and we now have sufficient experience to qualify us to judge for ourselves of our own needs. It will appear further on that some of the conditions of signaling in the navy are widely different from those governing army practice. We have, therefore, ample data upon which to strike out for ourselves in this important matter.

In the discussion of signal codes in general, the following tabulated synopsis will outline briefly the method here presented:

- **Signal Codes.**
  - **Limitations.**
    - **Distance.....**
      - Ordinary.
      - Long.
    - **Meteorology.....**
      - Day.
      - Night.
      - Gales.
      - Fog, mist, rain or falling snow.
      - Refraction, etc.
    - **Topographical..**
      - **Land.**
        - Desert.
        - Woods.
        - Hills.
        - Valleys.
        - Mountains.
        - Water.
      - **Sea.....**
        - Rough.
        - Dip of horizon.
    - **Enemy .....**
      - Ordinary communication cut off by enemy or by smoke of battle.
  - **Elements.....**
    - **Number of—**
    - **Kind.....**
      - Sound.
      - Time.
      - Motion.
      - Color.
      - Form.
      - Position.
    - **Groups or Characters.**
      - Alphabetical.
      - Numeral.
      - Special.
    - **Display.....**
      - Transient.
      - Permanent.

We start first with the limitations of signaling in general.

Rapid and accurate communication between the different parts of organized military forces, both afloat and on shore, is of vital importance. The limitations of military signaling in general are, roughly speaking:

1. *Distance.*—At sea the dip of the horizon limits the range of signaling, and mechanical difficulties add greatly to the problem. On shore modern inventive genius has in a measure solved most of the problems of distance by the use of telegraphy and heliographing for military signal purposes, while both afloat and ashore carrier pigeons offer a restricted field of usefulness.

2. *Meteorology.*—Fog, mist, rain, falling snow, gales of wind, and the conditions of the atmosphere as regards refraction, etc., affect materially the methods which are available for communicating or signaling. Under this head we may also classify daylight and darkness, that is day and night.

3. *Topography.*—The character of the land or water, hills, valleys, mountain ranges, deserts, woods, etc., determines also the character of the methods we may use in communicating. At sea the chief limitation of topography is the dip of the horizon, which is in itself one of the restrictions imposed by distance.

4. *The enemy.*—In time of war the presence of the enemy in force between signal stations, the smoke of action, and the exigencies of battle may require the use of special methods of communication; for instance, in the recent labor troubles at Homestead, Pa., the militia surrounded the steel works, one division being encamped on the opposite side of the river. Owing to the smoke from the mills and the vigilance of the strikers, ordinary communication with wig-wag flags or telegraph was cut off between the two main divisions of the militia. The heliograph was brought into use and the reflected sunlight readily pierced the smoke, and messages were read without difficulty.

On shore to communicate rapidly and accurately, four methods are available under some one of the above limitations, viz.:

1. *Messengers.*—Messenger service is here taken to include all means of sending a verbal or written message by a bearer; for instance, by an orderly mounted on horseback, or bicycle, or in some vehicle of transportation, such as a wagon, railway or balloon. It also includes pigeon service, which is a valuable adjunct to any means of day communication.

2. *Visual signaling.*—This includes all methods of transmitting a prearranged code by the motion of some object, by the display of certain symbols, shapes, or lights, or by the flashing of light.

3. *Phonetic signaling.*—In this the same object is accomplished by the emission of sounds of different characters; as, for instance, by gun-fire, bugle, bell, drum, gong, whistle or siren.

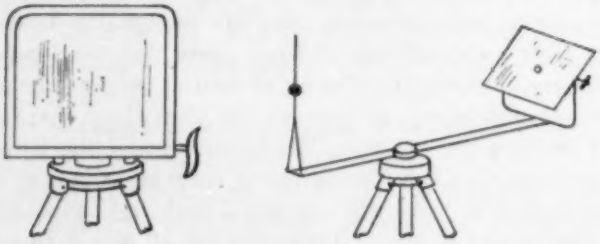
4. *Telegraphy.*—With a well organized field corps, and an outfit including wires, transmitters, poles, wagons, batteries, telephones, balloons, etc., we have in telegraphy the highest development of military signaling.

At sea the conditions are somewhat different. Dispatch vessels and the other auxiliaries of a fleet carry messages, and the pigeon service has a more limited application than on shore. Visual and phonetic signaling are, however, admirably adapted to naval uses, but telegraphy between vessels is as yet not feasible, although telegraphy by induction at sea has passed its earliest experimental stages and may be perfected in the course of a few years. However, at the best its range will be short and its usefulness restricted to less than long visual distances. In other words, telegraphy and heliographing from high stations, combined with balloon and pigeon service, give a very long range of communication on shore; at sea the curvature of the earth, the absence of elevated stations except by captive balloons, the impracticability of telegraphy and distant heliographing, all combine to restrict the range of signaling, and, as before stated, make the problem of distant signaling at sea one of the hardest to solve.

It would seem that army and navy signaling should involve the same underlying principles, but, curiously enough, the development has been along such radically different lines that the fundamental principles are surprisingly different, at least as between the methods used in our own army and navy. In the army the principal methods used are the wig-wag, the telegraph and the heliograph. These cover nearly all the conditions of strict signaling, as at night the torch is used with the wig-wag and a flash light with the usual type of lantern and shutter. These methods all aim at communication with only one station at a time, that is to say, to wig-wag, telegraph, or heliograph from one station to another. All around visibility or audibility is not a factor. In the navy we have sought and are seeking the development of methods which give visibility all around the horizon, so that a squadron can see the signals from any direction. Later on, in the consideration of the theoretical principles of naval signaling, it will be shown that the objections to

flags and to the semaphore are largely that they do not possess this virtue of all around visibility. It is very important, therefore, at the very beginning of the consideration of naval signaling to point out the capital error of adopting army codes and methods in our navy.

Let us first take the heliograph. In our western territories, during several Indian campaigns, the heliograph was used most successfully. In the military department of Arizona from November, 1889, to May, 1890, a chain of heliograph stations 2000 miles long was maintained in Arizona and New Mexico, completely networking the country in which the hostile Indians usually operated. The main stations were on mountain peaks, some 8500 feet above the sea level, and were from 50 to 100 miles apart. Connected with these were numerous secondary stations, forming a complete network over the territory embraced in the main lines of communication, so that any movement of the hostiles was rapidly reported to headquarters. The entire scheme was under the management of and developed by Col. W. J. Volkmar, U. S. Army, of the Adjutant General's Department. Two sizes of mirrors were used, 4½ and 8 inches square, for short and long ranges respectively, although the smaller size was successfully used on the long ranges. These were mounted on one end of a sighting arm that was itself mounted at its middle point on an ordinary



tripod. Through a small unsilvered spot in the center of the mirror, this arm could by the eye be pointed at any station and clamped in position. On the end of the sighting arm opposite the mirror, sliding on a vertical sight-bar or rod, was a small round disc. To adjust the instrument on the distant station, the disc was moved up or down so as to just mask the view of the station from the eye at the unsilvered spot on the mirror. The mirror was

capable of a slight lateral motion on its horizontal axis by means of a tangent screw, and of a revolving motion around the said horizontal axis. The object of the disc and of the unsilvered spot on the mirror was that when the unsilvered spot cast its shadow, so to speak, on the disc in front of it, the full beam of reflected light from the mirror was on the distant station. This enabled an assistant operator, by adjusting the axis and turning the mirror gradually, to follow the sun in its change of altitude and azimuth, and to keep the beam of light constantly on the distant station; for all he had to do was to keep the disc unilluminated by the unsilvered spot. Some three feet in front of the mirror was another tripod carrying a vertical shutter or screen, operated by a lever so as to fall flat or rise to a vertical position at the will of the operator. This shutter, when vertical, masked the beam of light thrown by the mirror towards the distant station, and by working it the beam could be flashed on the dot and dash system, using the Morse code. To call the distant station the beam was turned on steadily till answered. If at any time the sender's mirror got out of adjustment so that the distant station failed to see it during the course of a message, the distant station turned on its beam of light to stop the message till re-adjustment was effected. So successfully was this means of communication operated that, on May 14, 1890, partial communication was established between the stations on Mt. Graham and Mt. Reno, a distance of 125 miles. Two stations with one intermediate covered 195 miles. Constant communication was kept up between Mt. Graham and Lookout Peak (Sierra Anchas), 105 miles distant, and between Mt. Graham and Fort Huachuca, a distance of 90 miles. The altitude and the remarkable clearness of the atmosphere were, of course, favorable to such remarkably long ranges. As previously noted, the heliograph was used this summer at Homestead under peculiar circumstances, illustrating its value in smoky weather and with stations separated by the enemy.

The navy has blindly followed the army in the matter of signal codes ever since the Civil War. In all the three codes which we have gotten from this source, viz., the Myer, the Continental Morse, and the American Morse, we have copied the instructions for heliographing as if we seriously contemplated using this method. Heliographing is not possible from one ship to another, nor from a ship to the shore, nor from the shore to a ship. Absolute immobility is

required in the receiving and transmitting stations. This we do not get in either a ship at anchor or underway. Heliographing from its name implies the use of the sun's rays. It is a method of visual day signaling. It is adapted to high altitudes where the disturbing effects of refraction and the convection due to heat rays is inconsiderable. Along the coast at the sea level it has a most limited range of usefulness. It is essentially not adapted to naval purposes. What we use and what we want is a flash light or lantern, which is a very different sort of an affair, as it gives visibility all around the horizon. Of couse it is well enough to know how to use a heliograph in the navy and how to signal with one, for they are useful in triangulating work, such as is done on the coast of lower California and Mexico, but, as a method of naval signaling, heliographing is not especially useful in cruising.

The army, in June, 1889, adopted for signaling the American Morse code in place of the Continental Morse. It is as follows:

ARMY AND NAVY CODE FOR VISUAL AND TELEGRAPHIC SIGNALING.

American Morse Alphabet.

A · —	F · — ·	K — · —	P · — — ·	U · · —
B — · · ·	G — — ·	L — —	Q — — · —	V · · · —
C — · — ·	H · · · ·	M — —	R · — ·	W · — —
D — · ·	I · ·	N — ·	S · · ·	X — · · —
E ·	J · — — —	O — —	T —	Y — · — —
		Z — — · ·	& · — · · ·	

Numerals.

1 · — — — —	3 · · · — —	5 · · · · ·	7 — — — · ·	9 — — — —
2 · · — — —	4 · · · · —	6 — · · · ·	8 — — — — ·	0 — — — —

Punctuation.

Comma · — · — —	Interrogation · · — — · ·	Parenthesis Pn
Semicolon S,	Quotation Qn	Bracket Bx
Colon Ko	Paragraph · — — — —	Dollar Mark Sx
Period · — · — · —	Exclamation — — — — ·	Dash Dx
	Hyphen Hx	Underline Ux

NOTE.—A fraction is made by inserting a dot between the numerator and denominator. Example: $\frac{1}{2}$, · — — — · · — · · — — — —

The reasons which led up to this change were good and sufficient ones, considering the problem solely from an American standpoint. We have no military telegraph lines to speak of, and in any operations in our own country, as, for instance, in recent Indian wars, messages must be sent over commercial lines. The operators are skilled in using only the commercial code, and, besides the vast number of operators offers an inexhaustible supply on which to draw in time of war. The many theoretical and practical defects of this code are gotten around the best way possible in the wig-wag and by the heliograph for the sake of the advantage the code offers in telegraphy. Now, from a naval standpoint, no advantage accrues to us from adopting such a code. We do not want telegraph operators on board ship; we have no signal corps to recruit, and we have no telegraph lines.

This code was invented before the principles of signaling were at all understood, and has been in use so long that it is now impossible to either correct its defects or substitute any other for it. The best military codes have only two elements. The American Morse has four, viz., the dot, the dash, the long dash, and the space. When this is transmitted by a wig-wag flag or a torch, the dot is a motion to the right, the dash is a motion to the left, the space is a motion to the front, the long dash is made by pausing in the motion to the left and holding down the flag or torch for a preceptible interval; the "front" or space between words is made by introducing a slight pause before and at the end of the front motion to distinguish between it and the space in the letters c, o, r, y, z and &. In other words, in addition to the elements of motion right, left and front, a pause or element of duration is introduced. This is objectionable, as it brings tension on the eye to catch the pauses, and in long range signaling, when the receiver uses a glass to aid the eye, it is very trying. An alphabet and numeral code require only thirty-six characters. With only five elements in each character, that is a *maximum* of five and a *minimum* of one, *sixty-four* permutations and combinatious of two elements are admissible, yet this code goes to all the trouble to introduce characters containing six and seven elements, and that, too, with four fundamental or unit elements to build upon. Using the four units, the theoretical number of possible permutations and combinations, with one as a *minimum* and six as a *maximum*, is 5460. However, as the space

can only come between the other elements, the practical number is much smaller, but still the three or four thousand possible, and the need for only some forty or fifty characters at the most, show how little theory entered into the considerations when the American Morse code was invented. The army may be able to put up with the many defects of this code in consideration of the other advantages which come with it, but for naval purposes the needs of a code cover a much wider range and impose most trying conditions. For instance, in the wig-wag, unless the sender is facing the receiver squarely, the space motion in the letters will invariably be taken for a dot or dash (according to circumstances). On shore, in communicating between stations, there is no difficulty in facing squarely. Afloat, on board a rapidly moving torpedo-boat or a vessel turning, the sender cannot always face the receiver squarely, particularly if sending to two or more vessels or receiving stations which are not close together. With a telegraph key and sounder which works quickly, the space is rather short, and rapid signaling is possible. Using a fog-whistle or an electric light to transmit this code, the slowness and deliberateness which must be used makes it necessary to prolong the element, as will be hereafter explained. The time elements of space and long dash add much to making this the slowest code invented. Practically on the fog-whistle this code is transmitted as follow: the dot is a short toot, the dash is a blast of at least two or three seconds, the space is a blast of five to ten seconds, the long dash is a blast of ten to fifteen seconds. Failure to distinguish between the long dash and the space letters leads to confusion in distinguishing the space letters, c, o, r, y, z, and &, from syllables containing the letter "l," such as ele, eli, ili, ile, sle and els. The time consumed is enormous. To make signal for a simple change of course requires some five minutes, during which time the blasts are almost continuous, approaching vessels cannot be heard, the people on the bridge are deafened, and the vessel itself is positively a danger to navigation. In some such system of night signaling as the Ardois or similar apparatus used abroad, there is no way to transmit the space letters, and a hoist of six lanterns is required to transmit the numeral *six*. As we are the only navy that uses as many as five lanterns, six would, indeed, be a step backwards. As a matter of fact, the American Morse code cannot be used on the Ardois, and in our service we have a special code called the

"Ardois" to use with the apparatus. These criticisms are only meant to bring out strongly the important fact that it is not safe to violate the fundamental principles of signaling in the construction of a code. There *are* principles in signaling and it is now proposed that we take up the theory of signaling and work out those principles, testing them afterwards by the conditions imposed in actual service. It is certainly unsafe for us to be guided by the conditions which determine the selection of a code by the army, when the objects to be sought and the topographical and meteorological conditions are radically different. The simpler the whole question of signaling can be made, and the fewer the codes which men have to learn, the better we will get along, as we have no corps of trained signalmen and we require practically all our officers and men of the active combatant force to be up on signaling.

The Theory of Signaling.

Signaling is the transmission of a prearranged code as accurately and rapidly as mechanical or other means will admit. All signals or codes are prearranged or preconcerted. The simplest are those of one element where the display of a certain motion, sound or symbol, a certain number of times or under certain circumstances, is taken by previous agreement to have a special meaning. For instance, a lantern, a handkerchief, a hat, or anything by which the attention is attracted. In codes of more than one element the elements are color, motion, sound, time, form or position, grouped to represent special characters, letters or numerals, or all three. The characters, numerals or letters may or may not in their arrangement make direct sense. The key is furnished usually in some book, or else the message is spelled out by means of an alphabet. Signals are of two kinds, *transient* and *permanent*. For instance, motions and sounds are transient because they disappear as soon as completed. Symbols, such as flags, shapes or lanterns, are kept hoisted or displayed till read, and are therefore classed as permanent. It will be found that symbols which answer for short distances generally fail at long distances, so that the question of signaling naturally divides itself into ordinary signaling and distant signaling. From a naval standpoint ordinary signaling is what may be called squadron or fleet signaling, that is, signaling within the limits imposed by squadron or fleet cruising. Under any circumstances a good code

is of the first importance. Expertness comes only with long practice. It is important, therefore, to limit the number of codes which a signalman has to learn to receive and transmit under varying distance, by day or night, or in fog or smoke. The observation of fundamental principles in the formation of a code gives flexibility and reliability.

The simplest military codes in general use are those based on the ten numeral characters. One element may be displayed from one to ten times, or groups of two or more elements, each group representing a numeral character, may be used, or ten different elements may be adopted, each representing a numeral character. One element signaling is too slow. Using ten elements, represented, for instance, by ten flags, gives rapidity, but is more complicated. As a rule, the greater the number of elements the greater the speed in signaling, but the more complicated it becomes, and the greater the mechanical difficulties. Instead of ten flags, we may use, for instance, ten different positions of a semaphore arm, or ten different shapes, or ten different displays of lights, etc. With a semaphore or wig-wag, or display of lights, the numerals of a group or combination are displayed successively, and in some forms of distant signaling the elements of each numeral character are also displayed successively. This is very slow, but the mechanical difficulties and considerations of visibility limit both the number of elements and speed in signaling. With the Very's night code, in which stars are fired from a pistol, the two elements used are red and green. The height to which they go and their visibility makes it a most excellent night code for distant signaling. The use of only two elements, the desirability of groups of four, and the requirement of high firing, restrict the speed of signaling. The code is as follows:

1.	R R R R	2.	G G G G
3.	R R R G	4.	G G G R
5.	R R G G	6.	G G R R
7.	R G G G	8.	G R R R
9.	R G G R	0.	G R R G

Another form of a night numeral code of two elements, in this case white and red, is that used in the German navy with the Conz electric night signaling apparatus. It is as follows:

1.	W	6.	R R
2.	R	7.	W R R
3.	W R	8.	R W W
4.	R W	9.	W W R
5.	W W	0.	R R W

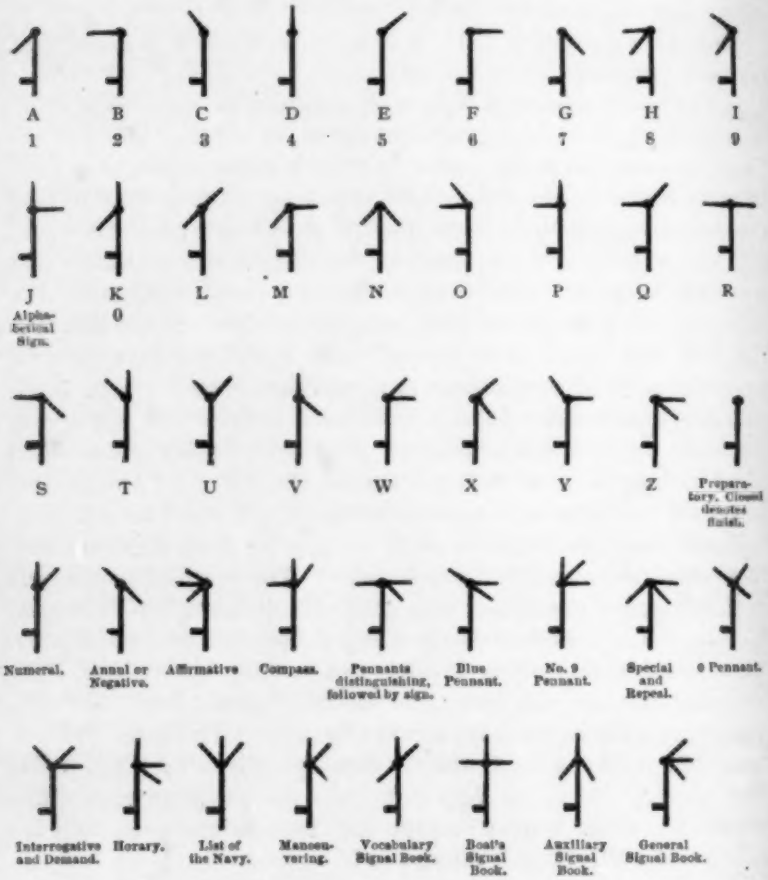
Four other signals, W R W, R W R, W W W and R R R, are used for code purposes.

In flag hoists the signal composed of a group of numerals is made in one hoist, and this gives rapidity in signaling. Limiting the hoist to four, the permutations and combinations, using one, two, three or four in a hoist, is 11,110, which, using code flags to give different meanings to the same display, gives ample range for a general signal book. It has, however, been found by experience that four-flag hoists are difficult to manage in a strong wind, and take time to bend on and hoist. If we limit the hoist to three, the possibilities are only 1110. The Italian naval authorities have adopted the consonants of the alphabet as represented by the eighteen International Signal Code flags. With three as maximum and one as minimum in each hoist, the total number of displays admissible, using the eighteen international consonants, is 6174. The step beyond this is to take all the letters of the alphabet and the ten numerals besides. In English this would give us thirty-six characters, and enable us to spell out any message. The scope of such a code is limitless, but to transmit it by thirty-six different flags is impracticable. In the French Mediterranean Squadron an experimental night code is used which involves two peculiar innovations. The two elements are red and white electric lights. By a make-and-break key these lights may be called flashing. This gives four elements in reality, a fixed white, a flashing white, a fixed red and a flashing red. As in our Very night code, the groups are each of four elements. If any display contains less than four elements, there is a mistake and the signal is disregarded.

In a semaphore code the elements are those of position, and each letter is displayed transiently in one motion. This gives great speed, but limits the code to visual signaling. There is no way of transmitting it phonetically or by flash. The night semaphore, using arms illuminated with lights or lighted up by reflection is not regarded as at all satisfactory. Many experiments have been made in the English navy, but the result is that the Continental Morse code is

used with a flashing or winker light, transmitting the dot and the dash. The English semaphore code is as follows:

ENGLISH SEMAPHORE CODE.



To construct an ordinary alphabet and numeral code two elements are used, and these are combined into thirty-six or more different characters. Two elements, limited to four as a *maximum* in any combination and with one as a *minimum*, give a possibility of only thirty different characters. With five as a *maximum* the limit is

sixty-four, which gives great scope, as only thirty-six are absolutely needed. In a theoretically perfect code of this character, the following conditions should obtain:

1. No elements of elapsed time, or duration, and no elements requiring a pause should be used, as the tension on the eye, ear, and brain is very trying.

2. Transient elements, such as those of motion, give speed in signaling, and are better than time elements.

3. Two elements, limited to a maximum of four in each combination to represent a letter, give the best results.

4. The vowels and letters which are on the average most often used should be selected from the simple elements or combinations having the fewest elements, in order to give speed in signaling.

5. Groups of symbols, representing words or complete phrases and sentences, should be separated by a positive character or symbol, instead of by a pause or time element of duration.

6. The numerals should all have the same number of elements in the combinations representing them.

7. No numeral signal should be made as such, without a distinctive signal "Numerals follow," and, on the completion, one implying "Numerals end."

These principles here enunciated may not, on grounds of expediency, be best in some particular method of signaling, but, for a general code adapted to all conditions, they will be found fundamentally sound and safe to build on. So many mechanical means of transmitting signals have, from time to time, been invented and tried, and each new invention has seemed to treat the theoretical requirements of a code with less and less consideration, that the result is theoretical considerations are either little understood or never heeded. Many of these mechanical devices are extremely valuable, but it should not be lost sight of that a good code is of the first importance, and the mechanical means of transmitting it is in a sense secondary. No change in a good code should be made simply for the sake of adopting a good mechanical means of transmitting it, unless the reasons therefor are of the utmost importance.

The simpler the question of signals can be made, and the fewer the number of codes that have to be learned, the less training signalmen will require, and the greater the number of officers and men that can become proficient. There is, of course, such a thing as sacri-

ficing too much to simplicity, but if one code can be made to answer for all the devices required for squadron and distant day, night, and fog signaling, then it is reasonable to expect that every officer and man in the combatant force shall know that one code thoroughly.

The two best known and most thoroughly tried military signal codes in the world are the Continental Morse and the Myer. The Continental Morse is in general use in Europe, and is as follows:

Continental Morse Alphabet.

A · —	G — — ·	M — —	S · · ·
B — · · ·	H · · · ·	N — ·	T —
C — · — ·	I · ·	O — — —	U · · —
D — · ·	J · — — —	P · — — ·	V · · · —
E ·	K — · —	Q — — · —	W · — —
F · · — ·	L · — · ·	R · — ·	X — · · —
	Y — · — —	Z — — · ·	

Numerals.

1	2	3	4
· — — — —	· · — — —	· · · — —	· · · · —
5	6	7	8
· · · · ·	— · · · ·	— — · · ·	— — — · ·
	9	0	
	— — — — ·	— — — — —	

In this code the distinction between the elements dot and dash is one of duration. The interval between the words is a pause. In transmitting it by a wig-wag flag or a torch, the dot is a motion to the right, the dash is a motion to the left, and the pause or time interval representing the space between words is a motion to the front. In other words, time elements of different values are transmitted by motions of equal value in point of time of making them. With the heliograph or winker light or on a fog-whistle, the dot and dash are distinguished by the greater duration of the dash. On the Ardois or Kasolowski, or similar system, the dot is a red and the dash a white light. By gun-fire the dot is transmitted as one gun a dot, two successive guns a dash. There is no positive character or "front" separating words and sentences, or groups of numerals, but a pause or element of elapsed time is used instead, which is one of the few defects of the code.

The Myer code is as follows:

Myer Code.

A	2 2	H	1 2 2	O	2 1	V	1 2 2 2
B	2 1 1 2	I	1	P	1 2 1 2	W	1 1 2 1
C	1 2 1	J	1 1 2 2	Q	1 2 1 1	X	2 1 2 2
D	2 2 2	K	2 1 2 1	R	2 1 1	Y	1 1 1
E	1 2	L	2 2 1	S	2 1 2	Z	2 2 2 2
F	2 2 2 1	M	1 2 2 1	T	2	End of word	3
G	2 2 1 1	N	1 1	U	1 1 2	End of sentence	3 3

End of message 3 3 3

Numerals.

1.	2 1 1 1 2	6.	1 2 2 2 2
2.	1 2 2 2 1	7.	1 1 2 2 2
3.	2 2 1 2 2	8.	1 1 1 1 2
4.	2 2 2 1 2	9.	1 1 2 1 1
5.	2 2 2 2 1	0.	2 2 2 2 2

In transmitting the Myer code by means of a telegraph key and sounder, the 1 is a dot, the 2 is two successive dots, and the 3, which is the "front" or interval separating words and sentences, is three successive dots. With the wig-wag, a motion to the right of the sender is a 1, to the left a 2, and to the front a 3. With the flash or winker light by night, or the heliograph by day or night, the 1 is a short flash, the 2 is two successive short flashes, and the 3 three successive short flashes. On the fog-whistle the 1 is one toot, the 2 is two toots and the 3 is three toots. Both the Continental Morse and the Myer codes have really three elements, for in the former the pause or elapsed time between the words is as much a third element as the three of the latter, but the two codes differ radically in their character. The Continental Morse is founded upon three elements, or elements of duration, viz., the dot, dash and elapsed time interval, whereas the Myer elements are those of motion or distant duration. Hence the latter is essentially a wig-wag code, because the motions to the right, left and front correspond to the motions 1, 2 and 3. As to which elements, those of time or those of motion, answer best for naval purposes, the follow-

ing comparison of the Continental Morse and Myer, as representing the best types of each, would seem to indicate that those of motion are superior to those of time. In the wig-wag both codes are transmitted with the same ease and rapidity, and no advantage rests with either. Indeed, as far as construction goes, we might convert one code into the other by making a dot a 1 and a dash a 2. On the fog-whistle it seems more easy and certain to transmit toots than to transmit blasts of varying lengths. A steam whistle, particularly in craft where the steam supply is not great, is not always reliable as to the emission of sounds. In the Myer code the sounds are taken as of equal value, although they may accidently vary in length, and the use of the "front" signal is an advantage, as it relieves the mind of all doubt and embarrassment as to the end of the word, as to abbreviations, as to end of sentence, and as to end of message. It also gives speed in signaling, as there is no need of pausing till the message is ended. Motions or short sounds, in groups of one, two or three, seem to lend themselves more readily to the eye and ear than dots and dashes. This may seem too subtile a distinction, but there are several things to be kept in view from the American naval standpoint. We have no trained signal corps. All the combatant force should know something of signaling. That which appeals to or strikes most readily the untrained eye and mind is best. Simplicity is the first consideration. For fog-whistle and heliographing the advantage in speed of signaling both in theory and practice rests with the Myer. By gun-fire signaling with the Morse code it is necessary to call the dot a 1 and the dash a 2 in order to transmit it, whereas the Myer code is all ready for use and needs no such modification. In naval signaling there can be no question but that the advantage rests with the Myer code as against the Continental Morse. It would be unfair however, not to point out one rather serious defect in the Myer. The front signal 3 is three toots on the fog-whistle and three short flashes by heliograph, which is the same as the letter Y. This leads to confusion, so when this code was in use in the navy the front was made by a blast on the whistle and by a prolonged flash with lights. The Continental Morse has no such "front." To introduce one would require the use of a *long* dash. This is objectionable on the fog-whistle and makes signaling slow. If we convert the Continental Morse into a Myer code by substituting a 2 for a dash, we would still meet with

the same difficulty, as the letter *s* is three dots, and we would have to use a dash for a "front."

The general adoption in the principal navies of the world of some such system of night signaling as the Ardois or Kasolowski apparatus by means of permanent hoists of red and white electric lanterns would seem to call for certain changes in the construction of the Continental Morse and Myer numeral codes, because the lanterns are for certain practical reasons hereafter stated now generally limited in number to four, whereas the Continental Morse and the Myer numerals contain five elements each. The following four-element numeral codes are here proposed to meet this requirement.

For the Continental Morse Code.

1. · · · · or h
2. – – – – or Cornet (genl. call.)
3. · · · – or v
4. – – – · or numeral call
5. · · – – or letter call
6. – – · · or z
7. · – – – or j
8. – · · · or b
9. · – – · or p
0. – · · – or x

Interval · – · –

We might, of course, change the foregoing to a Myer code by using 1 and 2 in place of the dot and dash.

For the Myer Code.

1. 1 1 1 1 or cornet (genl. call)
2. 2 2 2 2 or z
3. 1 1 1 2 or letter call
4. 2 2 2 1 or f
5. 1 1 2 2 or j
6. 2 2 1 1 or g
7. 1 2 2 2 or v
8. 2 1 1 1 or numeral call
9. 1 2 2 1 or m
0. 2 1 1 2 or b

Interval 2 2 1 2

It will be noted that there are only thirty possible combinations of the dot and dash or 1 and 2 limited to four elements as a *maximum*. On the other hand, there are twenty-six letters and ten numerals or thirty-six characters in all, to be provided for. This means that some of the numeral characters must duplicate the letters. In the above arrangements the consonants h, v, z, j, b, p and x are duplicated in the Morse, and z, f, j, g, v, m and b in the Myer

numerals. The intervals • – • – and 2 2 1 2 occur in neither the alphabet nor in the numeral codes proposed. They separate words, sentences, groups of numerals, etc., and are in other words positive "front" signals. The cornet is the general call to all vessels or stations in sight. When followed by an initial letter it calls a particular ship or station. The "letters call" indicates that the characters which follow are to be read as letters; in other words, as a spelled out message or as consonant signals, as in the International Code. The "numeral call" indicates that the characters which follow are to be read as numerals. It is the "numerals follow" signal, and no character is to be taken as a numeral unless preceded by this numeral call. This is exactly what is done in the English semaphore code. The numerals duplicate letters. The code call "numeral" is displayed when they are meant to represent numerals. It may be thought that in limiting the code to thirty characters too little latitude is allowed for call or code signals, such as telegraph, compass, international, action, etc., and for such special designating characters as interrogatory, affirmative, negative, annulling, preparatory, danger, etc. The following considerations, however, will show that this limitation is largely imaginary. In the wig-wag code all the special significations are provided for in our navy, as follows: The code calls are T. D. U. (telegraphic dictionary use), A. S. U. (action signals use), I. C. U. (international code use), S. B. U. (signal book use), N. L. U. (navy list use), G. L. U. (geographical use), and F. D. U. (fleet drill-book use). These cover all the code calls for all other methods of signaling, except the Very's night code, which is more limited in its scope for reasons hereafter stated, and any number of code calls can be added to cover future contingencies, such as C. A. U. (cipher "A" use), C. B. U. (cipher "B" use), etc. As all other methods of signaling, other than the Very and flag hoists, are alphabetical, the interrogatory, annulling, affirmative, preparatory, etc., can be made by abbreviations, such as "prep." "interrog." or int." etc. This question will be discussed under each method of signaling, which is hereafter described, as will be also the question as to four lanterns in the Ardois or other night electric code. To summarize, we have in the Myer elements of 1 and 2 two almost perfect elements. Certain modern conditions would seem to demand the use of four elements in the numeral characters. If those conditions are impera-

tive, we can easily accomplish this desired end. If a five element code is thought best or desired most, there is none better, both in theory and as demonstrated in practice than the original Myer code which we gave up in April, 1886.*

SYNOPSIS OF METHODS OF MILITARY SIGNALING.

- METHODS OF MILITARY SIGNALING.
  - ARMY SIGNALING.
    - 1. MESSENGERS.
      - Mounted orderlies.
      - Balloons.
      - Railways, etc.
      - Pigeons.
    - 2. VISUAL SIGNALING.
      - Wig-wag or semaphore.
      - Heliograph.
      - Flash light.
      - Flags and shapes.
    - 3. PHONETIC SIGNALING.
      - Bugle or drum.
      - Gun-fire.
    - 4. TELEGRAPHY.
  - NAVY SIGNALING.
    - 1. MESSENGERS.
      - Dispatch vessels.
      - Pigeons.
      - Balloons.
    - 2. VISUAL SIGNALING.
      - DAY ....
        - Ordinary (Squadron).
          - FLAGS
            - International.
            - Naval.
          - Wig-wag or semaphore.
          - Shapes.
        - Distant .....
          - Balloons.
          - Shapes.
      - NIGHT.
        - Ordinary (Squadron).
          - Chemical or pyrotechnic.
          - Electric.
          - Flash.
          - Semaphore.
        - Distant.....
          - Balloon.
          - Search light.
          - Chemical (Very's) or pyrotechnic.
    - 3. PHONETIC.....
      - DAY OR NIGHT.
        - Ordinary or Squadron.
          - Fog-whistle.
        - Distant.....
          - Gun-fire.

* Why the original Myer code was not used with the Ardois apparatus is difficult to conceive. The eight original outfits ordered abroad were marked with what is now called the Ardois alphabet. This has now been perpetuated in six new ones ordered in France, and for all those now contracted for in this country for the vessels building at navy yards. As each apparatus costs fully $1000, it is binding the navy for the future. With all our new ships thus fitted, there is little hope of a return to the Myer code, for it will then be both inconvenient and expensive. The so-called Ardois alphabet violates most of the principles of a good code. A is R W R, B is R W R W, D is R W R W R, H is R W W, O is R R, W is R R R, etc., etc. All alphabetical characters begin with an R (red); all other signals, such as code calls, numerals, etc., begins with a W (white). For instance 1 is W R, 2 is W R W, 3 is W R W R, 5 is W R W R R, 0 is W. This code is unfit for any other purpose. The Myer code would answer just as well on the Ardois apparatus and would be useful for all other purposes.

METHODS OF SIGNALING AT SEA.

The patents taken out in the various countries of the world for devices for signaling at sea would, in their published specifications, fill volumes. Those which have survived the crucial test of actual trial have not been many, but have been sound in principle. Methods which conform to certain conditions are inapplicable to others, so that in naval signaling we have numerous methods. Where one code is utilized for all purposes, expertness is as much a question of ordinary intelligence as it is of practice.

As previously stated, all naval signaling divides itself as to character into two classes, squadron and distant; as to limitations imposed by nature, into day, night, and fog signaling; and as to method, into messenger, visual and phonetic signaling. Distinction is also made as to the relative permanency of any signal displayed—that is, whether transient (disappearing as soon as made, such as a sound) or permanent (displayed until read and understood, such as hoist flags). Bad weather somewhat limits the application and range of any form of signaling. Fog, mist, or snow prevent visual signaling and also some forms of messenger service. Night and day reverse the forms of visual signaling, and distance by day destroys the value of color and increases that of form, whereas by night it increases the value of color and destroys that of form. Experience has demonstrated the value of certain forms and colors for visual signaling and of certain methods for phonetic and flash signaling. Unfortunately the data on which certain recognized standards have been adopted is not available, but an enumeration of the methods of signaling at sea will at least show that it has developed along certain well defined lines.

I.—Messenger Service.

By Dispatch Vessels.—Written messages are sent by dispatch vessels or by the other auxiliaries of a fleet. There are no limitations as to distance. A distinguishing or dispatch flag is usually displayed by such vessel to indicate the character of her mission, and as a notice to others that she is not to be interfered with. Speed and sea-going qualities are, of course, requisite under ordinary conditions of dispatch service, and for distant cruising coal endurance is a prime requisite. The dispatch vessel has been developed as a special

type in most navies, and, as an auxiliary of a fleet, when not employed in carrying dispatches, it is most valuable as a scout.

By Pigeon.—During daylight and for distances not over three hundred miles, communication by pigeon between vessels and the land is quite practicable. Between vessels at sea it has a much more limited application. Such communication is impracticable by night and in a fog, but is not affected by cold, rain or snow, except in the matter of speed. In France satisfactory experiments have been made in communication between ships of a squadron out of sight of each other, and out of sight of land. In the French navy a regular pigeon service has been established and has been used in squadron manœuvres. The birds are taught to alight or set out whilst the guns are being fired, so that they will be available for use in a general action. They know their own ship and fly with as much certainty at sea as on land. Abroad the whole question has passed the experimental stage, and pigeons are used, under certain circumstances, in the French, Italian and Austrian navies. In the United States, satisfactory experiments have been recently made from stations at Newport, R. I., Annapolis, Md., and Washington, D. C. The homing pigeon service, from experiments on the recent cruise of the Constellation, are said to have justified the hope that the service will be officially established in our navy. Several very important messages were sent this summer, and out of twenty-seven birds liberated all but two turned up, and these bore duplicate messages. About September 1, 1892, birds liberated from Fort Monroe covered the distance of 125 miles in excellent time, and all reached their destination. The steamer Waesland liberated a bird 315 miles from Sandy Hook at 1 P. M., and it was in its loft on shore the same evening. When released at sea, pigeons fly direct to land and then take their flight from shore bearings. On shore the longest record of one-distance flight is about 1100 miles, but in these cases numerous birds are let loose, and only a few reach their destination. Forty-six kilometers, or 28¾ miles per hour, is an average long flight, while 1370 yards per minute, or 46 miles per hour, has been recorded in exceptional cases. In Italy regular lines have been established between Rome and Madalena, and between Naples and Cagliari. The former is 150 miles long and averages five hours in flight, and the latter is 280 miles and averages nine hours. Experience has demonstrated that, to keep up frequent communication between such

distant stations, from 200 to 250 birds are needed for each line of flight. By pairing birds in one place and feeding them in another, what is known as "there and back flight" is obtained, and with this it is possible to keep up a continuous to and fro flight between two stations. At sea this finds its best application with light-ships and off-lying stations in communicating constantly with the shore where the distance is not over 50 miles. In October, 1883, a light-ship broke adrift from her moorings in heavy weather twenty-two miles from Tornung, off the mouth of the Eider. Four pigeons were liberated from the ship and brought the news in 58 minutes. The messages are usually carried in a section of goose quill, about 1¾ inches in length and hermetically sealed at the ends. Light wooden cases are also sometimes used. They are fastened securely to one of the underneath tail feathers. The birds are marked either on a light aluminum band around each leg, or by a stencil mark on the underneath side of the wing, or both. They are also sometimes spotted with certain dots of different colored paints on the back and wings. In the Austrian navy the only station is at Pola, where they have 120 pigeons. Several flights from ships down the Adriatic to the home loft have exceeded 250 miles. In Belgium the government has no regular lines of communication, but 600,000 birds are owned by private individuals or clubs for sporting purposes. France has some 100,000 pigeons. It is estimated that 25,000 pigeons would be required in war time for Paris and its outlying circle of forts. Switzerland and Austria are developing their systems. Berlin has two lofts of 500 pigeons each, and Ham, Metz and Strasburg each 1000 birds. In 1888, Germany had 52,240 birds available. Spain has 18 stations and Russia has numerous stations on her western frontier. Messenger service by pigeon is a most valuable method of distant signaling at sea, and should receive the development and encouragement which its great value merits.

By Balloon.—Under certain very peculiar circumstances balloon messenger service may be utilized for naval purposes, as, for instance, off a blockaded port, with a favorable wind to make a free ascent and descent either from shore to seaward, trusting to being picked up by friends, or from seaward to shore to communicate with friends in the blockaded port. The use of a sea anchor in making a descent, and drifting at sea till picked up, makes one phase of this hazardous service at least practicable under some circumstances.

Going from seaward to shore is not nearly so hazardous, and under some circumstances might be of great importance. Pigeon service would, in this case, serve most purposes. The general subject of ballooning, as applicable to naval signaling, is considered under the head of Visual Signaling, where captive balloons are utilized. This form is both feasible and valuable, and is described in detail. Of the recent French manœuvres (1892) in the Mediterranean, the *Army and Navy Gazette* of August 20th says:

"A chief purpose of these manœuvres was to test the working of the semaphore and carrier pigeon service, as well as the captive balloon. The semaphore stations proved their efficiency, and Admiral Brissonby, in command at Toulon, was kept *au courant* with the progress of affairs, and was able to direct the whole of the defence (against the supposed attack on that harbor). Doubtless these stations and their telegraphic apparatus would be the object of an early attack in case of war. The despatches carried by pigeons reached the commander irregularly, some being promptly brought while others were long delayed. As to the balloon, it burst and was useless." (This refers to a captive balloon.)

II.—Day and Night Squadron and Distant Visual Signaling.

Day Visual Signaling.—Day visual signals are, as to character, either permanent or transient. Bad weather limits the application and range of either form. Fog, mist, or snow destroys their usefulness for the time being, and phonetic signaling must then come into play. The elements of visual signaling are form, color, duration, position and motion. With flags we have both form and color; with shapes we have form only, although color may come into play at short ranges; with the semaphore we have position; with the wig-wag we have elements of motion, and with the heliograph we have elements of duration. Heliographing is not here regarded as a method of naval day visual signaling, as its application is strictly limited to use on shore. In messenger service we have seen that the same general means exist afloat as on shore, although more restricted at sea both as to range and rapidity of communication. As regards telegraphy there is no limitation as to distance, and the speed and capacity of signaling have been in recent years most marvelously developed, but from a naval standpoint the telegraph wire and cable are only indirect means of occasional communication from one base on shore to

another. As previously stated, the development afloat has been in the direction of all around visibility. This points to the use of shapes for general squadron signaling. Mechanical difficulties are largely a drawback to the development of this method. Experiment is necessary and should be entered into seriously in our service. It promises much in the simplification of the code, as with the use of shapes the same code as used in the wig-wag and Ardois could also be used.

Flags.—Flags possess the great advantage that in one hoist three or four elements can be displayed at once, and for general signal purposes thousands of permutations and combinations can be made. The objections to the use of flags are that in a calm they hang limp; in an unfavorable breeze they fly on; in haze and smoke the colors cannot be distinguished; the colors get dull and soiled through the effects of smoke, powder gases, sunlight and rain; and in action the halliards are so liable to get shot away. The greater the number of flags in a hoist the greater the chance of making a mistake in reading the signal; also the longer it takes to bend on and hoist a signal. Using 10 flags and no repeaters, the chance of mistake in a one-flag hoist to the chance of mistake in a two-flag hoist is as 10 is to 10x9, or using 20 flags and no repeaters as 20 is to 20x19. The simpler or fewer the colors in a flag the less liability to make a mistake in reading, particularly if the breeze is light. The smaller the flags the quicker they can be handled, but the more limited the range of visibility. Mechanical devices and practice increase the rapidity of flag signaling. Snatching the halliards and running away with them on deck; devices for bending on and detaching quickly; putting lead weights on to bring them down quickly; all these add to smart signaling. Using different shaped flags to indicate the character of the signal from the shape of the uppermost and the number in the hoist, leads to quick reading. Experience has demonstrated that the buntings which possess greatest visibility are of the colors *red, canary yellow, black, white and blue.* Much, however, depends upon the way they are combined, upon the character of the light, and upon the colors not fading easily. As between white and canary yellow, the former soils easily, and on the fly end of a flag lacks visibility. Red with blue is also a successful combination. White is a good intermediate color with red or blue in horizontal or vertical stripes, or in a square patch on a red or blue field, but it is

poor as the fly or hoist of a flag or as a single color. Bunting should be rigidly tested in respect to fastness of color and non-liability to fade. No more than two colors should be used in any one flag, as the chances are increased of mistakes where the flag droops and only a patch of color shows. The five colors red, white, blue, black and yellow give a wide range of two-colored flags and pennants.

1. International Flags. By international agreement eighteen flags, representing eighteen consonants of the alphabet, are used in hoists of two, three or four flags to communicate at sea between ships, or between ships and shore stations, using a code book in which the meaning of each hoist is given. The total number of permutations possible, using more than one flag and not more than four, in which no flag appears more than once, is 78,642. Two flag signals having the letter B uppermost are attention signals; with a pennant uppermost, compass signals; and with a square flag uppermost, urgent signals. The three flag hoists are universal and express latitude, longitude, time, weights, numerals, and all ordinary sea signals. Four flag hoists, having the B flag uppermost, are geographical signals; with the pennant uppermost, are spelling and vocabulary signals and names of men-of-war; and with the square flag uppermost, they are the names of merchant vessels. Of these combinations, 1440, from G Q B C to G W V T, are allowed for distinguishing signals for men-of-war, and 53,040, from H B C D to W V T S, are for merchant ships. The assignment of these combinations to the names of ships is left to the government of each nation within the limits prescribed. The French Government has recently proposed to the United States and Great Britain certain changes, which are numerous in detail as to the additional signals required, and also as to the modifications and corrections of signals now in use; for instance, to give each flag a special significance, as F, "end of word," K, "repeat," G, "do not understand," etc., etc. The

main proposition, however, is to add two letters, X and Z, which are to be represented by two yellow and black pennants. This

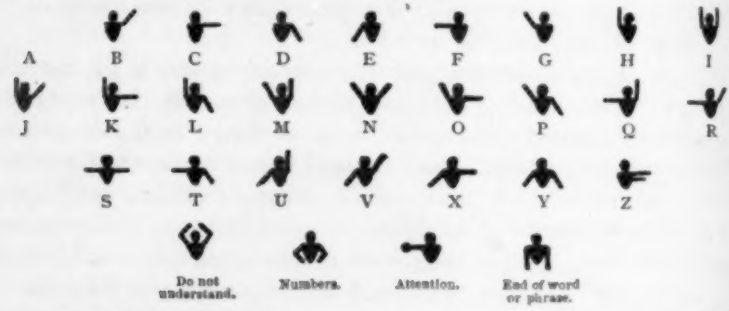
would increase the permutations from 78,642 to 123,500. In the main, the suggestions are in the direction of widening the scope of the code and increasing its efficiency. The increased speed of vessels and the rate at which they now pass one another at sea render quick signaling imperative, and the French are more keenly alive in these matters than any other nation. The British Government has submitted to France and to the United States a proposition to consider the extension of the international code to night signals and to adopt a phonetic code for certain purposes in foggy weather. No action has as yet been taken. In the Italian navy the international flags have been adopted for general signaling. The advantage to be derived from this is that using two and three flag hoists a total of 5,202 permutations are possible, which answers for all ordinary signaling; using four flags will add 73,440. Special code books are used, and only a few special and additional flags are needed for distinctive and code purposes. In the International Code no signal has ever more than one significance. The character of the upper flag and the number of flags determine its character on sight. Admiral Gherardi has submitted to the Navy Department a most excellent scheme for using alphabetical flags. As the international possess most of the virtues as to colors, etc., it would seem advisable to follow the example of Italy. It would simplify the study of signaling, and there is no advantage in making it difficult.

2. Naval Flags. Each nation has its code of flags which, when hoisted, convey special meanings interpreted in books specially devised and intended to be kept secret. As far as the secrecy of the alphabetical or numerical significance of each flag goes, it is of little importance. The key to the meaning is the important thing. The usual basis of the flag codes are the ten numerals, each represented by a special flag. Using 1st, 2d and 3d repeaters, the permutations and combinations using ten numerals and limiting the hoist to four flags gives 11,110. The English use a fourth repeater or substitute, which gives a five-flag hoist. They use altogether 58 different flags. The French have the most elaborate system of flag signals in the world. They have four sets of numerals. The first series are square flags, the second are "trapeze" shape, and the third are pennants. Separately each flag has a special meaning. The fourth is a telegraph series with nine square flags and five pennants. They can tell the character of signal by the upper

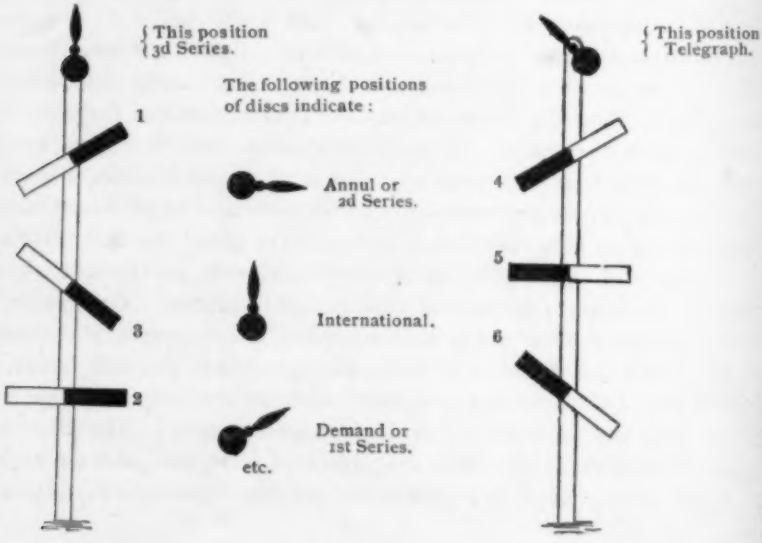
flag. The total is 51 numeral flags. Their flag signaling is so complicated that there is an official movement on foot to abolish their use altogether and substitute shapes. In our navy our signal books are very antiquated and few signals have been added. We have nothing on torpedo-boats and little or nothing on any modern appliances adapted to new ships. The modern demand is for one, two and three flag-hoists. We can certainly get in the numbers from 1 to 999 all the important signals. In any revision of the signal book, now so urgently demanded, the index columns should be arranged for either numerals or consonants (that is for both). In case shapes supersede flags they will probably be on the basis of numerals, although not necessarily.

The Semaphore.—Many officers in our navy, struck by the efficiency of this method of signaling as used aboard British vessels-of-war, have suggested its adoption in our service. Its supreme virtue is rapidity of signaling. Each character is made by practically one motion of one or more arms, which assume a definite position at which they are read. It is a three element code, it has forty-four characters, and it duplicates, with its ten numerals, ten letters of the alphabet. It possesses the same defect as the wig-wag, that it can be read only from one direction. An attempt has been made in the British navy to use the semaphore for night signaling. To this end the arms have been illuminated by reflected light or by lights on the arms. On the Nile and Trafalgar, and also on the Chilian armored cruiser Captain Pratt, light steel semaphore arms (perforated for lightness) have been fitted at the mast-head for signal purposes. There are two sets, the upper one for abeam and the lower for ahead. They are worked by endless chains running up the hollow steel mast operated from the berth deck. This is the development of the semaphore in the direction of increased visibility, both in increased size of arms and in the altitude at which mounted, and represents really the semaphore for distant signaling. It is not regarded as a pronounced success. One reason is that the lost motion in the endless chains leads to wrong positions of the arms. For day signaling the arms are painted black. Where the semaphore has been used at night, the arms have been painted white so as to reflect the light thrown on them. The defects of the semaphore are that it is a complicated code, hard to learn and to remember, that it is only adapted to day signaling, that it is

only visible in one direction, and that it cannot be used as a code for any other than the one purpose. In other words, it lacks simplicity and is limited in its range of usefulness. In the British navy, with its highly trained and well organized signal corps aboard each ship, and in the French navy, with the sea-coast defenses entirely in the hands of the navy, the question of simplicity is not so important as with us, where we expect so much from our combatant force. The code used has been explained. Using small hand-flags the code is transmitted as to method as follows, which is, however, the French semaphore code. Using the hands:



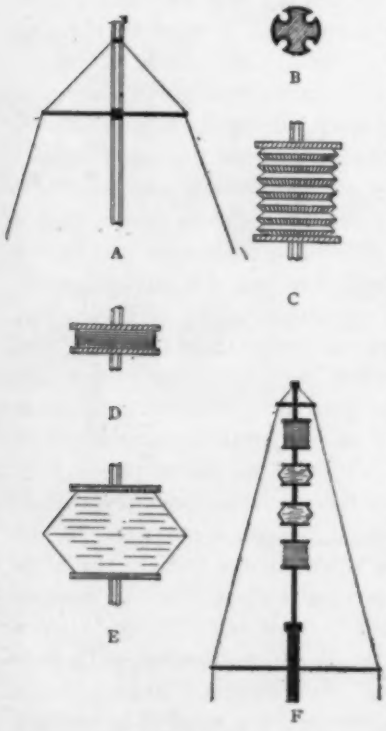
The French mechanical semaphore uses the same code as is used with the flag signals. It is manipulated as follows:



Wig-wag.—The elements are those of motion; the display of elements is successive and transient, and the method is slow. It possesses the defect that it is only visible in one direction. It is a most excellent method for our purposes because it can also be used at night by means of a torch; its elements are simple, it is easily learned, and with some such code as the Myer, it is adapted to all purposes of signaling. The code calls are initials such as T. D. U., G. L. U., etc.; the annulling, affirmative, repeat, error, etc., are special characters, and all other significations are spelled out. It is slow, but it is very simple, and we would make a great mistake to give it up for a semaphore code. In the German navy, using the Continental Morse, a dot is made by holding one flag out, a dash by holding two flags (one in each hand), and a front by crossing both flags over the head.

Shapes.—In squadron day visual signaling the use of shapes is only a matter of experiment. No navy has finally adopted them. The French are conducting some experiments, but the only information given out is that collapsible shapes are used, and that these are mounted on three arms projecting in the same plane from a common pivot. They are turned towards the observer just as the semaphore is. This destroys or neutralizes all the advantages of such a scheme, because, if we use for shapes figures of revolution, then from every point of the horizon each shape looks the same, and if we mount them on arms and confine their visibility to any particular direction, we destroy the one great advantage shapes possess over flags. If we turn them so as to display them successively to all points of the horizon, then we get visibility, but at the expense of speed of signaling. Unquestionably, the development of signaling by means of shapes is not along the lines practiced by the French. Collapsible shapes should open by one motion and close by reversing it. They may be made of canvas fitted to steel or wooden frames, and the collapsing motion may be made by a spring. The two most satisfactory shapes, from a mechanical standpoint, are cylinders and cones. If only one shape is displayed at a time the elements are made successively and the method is too slow for squadron purposes. The writer holds that the Myer code, using with it the four element numeral code proposed, is the ideal naval signal code, adaptable to all modern conditions. Also that the code is of the first importance, and that the means of transmitting

it somewhat secondary. To transmit this code by shapes we must have one shape to represent a 1, and another to represent a 2. To display all the elements of any character at one time we must be able to exhibit four shapes in one hoist or one display. The writer has unofficially submitted to Commander Sigsbee, U. S. Navy, whose inventive talent is so well known, a device for displaying shapes to conform to the Myer code, and it is his opinion that with several important modifications the scheme of shapes is feasible and practical mechanically. The device as modified by his valuable suggestions consists roughly of the following parts:

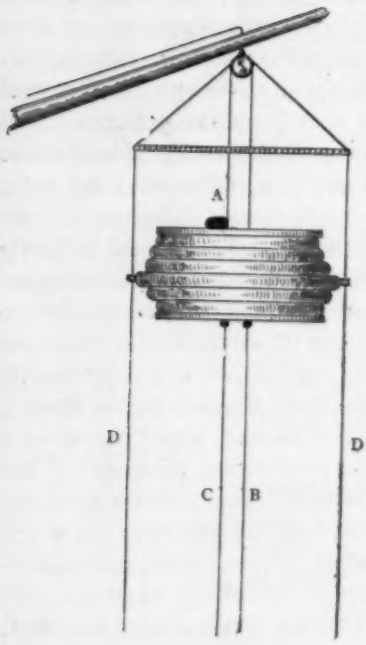


1. A signal mast of steel or wood with four grooves running its entire length, of which the positions are shown in *B*, which represents a section of the mast. This mast to be at least forty feet long, fitted with ordinary stays and backstays and with shrouds spread out or sprung out near the masthead to give clearance for making shapes on the mast.

2. Four shapes consisting of two light steel circular discs joined by a circular diaphragm of rubber, similar in general construction to a Japanese folding paper lantern. The lower disc is fixed to the mast, and the upper one can be raised by means of a cord which runs up a groove in the mast and over a sheave in the truck. When this is done the figure presented is that of a cylinder, as in *C*. When collapsed it takes the shape shown in *D*. Traveling on the mast is a loose collar inside of each shape fitted with steel ribs, somewhat like those in an umbrella. When the collar is held and the shape expanded, the umbrella frame opens out and gives the shape the appearance shown in Fig. *E*. The cords or wires which operate the display

and collapse of the figures travel in the grooves in the mast, and are worked by levers either in the tops or on a signal platform, or from deck. [It would be practicable, as in the English semaphore apparatus, to run the halliards and other signal gear inside a hollow steel mast and work the shapes from the berth deck.] Calling Fig. *C* a 1 of the Myer code, and Fig. *E* a 2, such a display as Fig. *F* would read 1221, that is, the letter M or the numeral 9 of the modified code. The discs might be made from 2½ to 3½ feet in diameter, and the shapes given a hoist of from 4½ to 6 feet. They would be easily visible from four to five miles from any direction of the compass.

If the shape representing 2 should be found by experiment to offer mechanical difficulties in operating the umbrella-like frame, we might substitute for it a collapsing ball, which would ordinarily house around the mast, inside of the space covered by the shape 1 when it is hoisted. This ball, when collapsed, would consist of a closely packed bundle of flat steel ribs surrounding the mast. When the upper collar is forced down towards the lower one, the steel ribs would take the form of a globe, which would represent a 2 of the Myer code, or a dash of the Continental Morse. The greatest difficulty in working shapes is experienced in blowy weather. The effect of the wind is to bind the steel discs, in the shapes proposed, to the mast, and prevent their being hoisted or collapsed. The effect of the mast is to steady and guide the shapes, and the form proposed would seem to offer less objection in bad weather than any other. British vessels-of-war are fitted with collapsing drums, which are rigged some 20 feet or more above the deck to a gaff of some kind, and are opened and collapsed on the dot and dash principle of the Morse code. They are barrel-shaped and, when expanded, the dimensions are as follows: height, 4 feet; greatest diameter, 3 feet 6 inches; diameter of heads, 2 feet 8 inches. They are rigged as shown in sketch. The drum is steadied by the guys *D*, and raised and collapsed by the ropes *C.* and *B.* *A* is a weight of 10 pounds to collapse the upper half by gravity. As shown in the sketch the drum is only partly collapsed. When completely so the thickness is only 8 inches. This is a device for fleet signaling at as great a distance as has yet been found practicable in the British navy. During the manœuvres recently, these drums were found to be much too small. The subject will be discussed further under the head of "Distant Day Visual Signaling." It is a very slow method



of signaling, but it represents one step in the direction of the use of shapes, and is a further movement on the part of the British navy away from the semaphore for anything like distant signaling. If used for distant signaling, powerful tesescopes are needed, and the height above deck must be increased.

The shapes proposed by the writer, operated on a mast specially constructed for the purpose and of sufficient size to be visible five miles, would seem theoretically to possess the following advantages: 1. Visibility from every point of the compass; 2. Ability to transmit an alphabet or numeral code; 3. Simplicity and uniformity in that the same code can be used for this as for all other purposes. If flags are to go, some such system must take their place.

Distant Day Visual Signaling.

Distance destroys the value of color and increases that of form. In our navy our largest numeral signal flags are eleven feet long. At a distance of between four and five miles, under the most favorable circumstances, with strong glasses, the limit of visibility as to color is reached. The shapes of the flags can be made out at five miles or more. The development of methods of distant signaling must, therefore, be in the direction of shapes of some kind. The dip of the horizon, of course, limits observation, so that any method must fail at a certain distance. Before discussing the question of apparatus, it may be well to outline briefly some experiments made abroad in naval ballooning for signal purposes. A captive balloon carrying a signalman gives, of course, an increased range of visibility for observation and signaling.

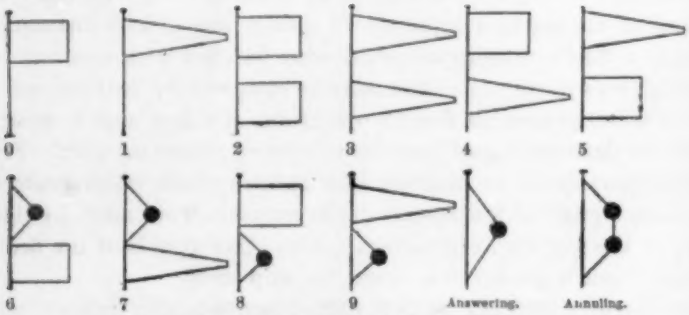
First, as to some recent experiments: On Sept. 6th, 1890, the torpedo-boat L'Audacieux, with a captive balloon, attached by a short cable, steamed from Toulon harbor to Hyères roads, a distance of twenty-one miles, in two hours. The balloon was transferred to the St. Louis, the gunnery ship, and the captain ascended and gave orders to his ship by telephone at a height of 250 meters. Lieutenant Serpette ascended, cast off the cable, and made a free ascent of 1800 meters. He came down in the open sea, and by means of a sea anchor, hereafter described, he waited till he was picked up by a torpedo-boat, which towed the balloon in. Afterwards the balloon was taken on board the Formidable, and was filled behind the armored turret on the after deck, hauled to the mizzen-top, and several officers successfully made a captive ascent. They ascertained that in clear weather all the details of the coast from Marseilles to the extreme point of the island of Hyères were plainly visible, and that no building or ship for 30 or 40 kilometers around could escape the notice of an observer in a balloon. The bottom of the sea to a depth of 25 meters was clearly distinguishable, and the movements of a shark were watched with interest. On the high seas no special value may be assigned for balloon service for reconnoissance, but for the operations of a fleet near a coast, in attack or defence, it may be made to play an important part. From a signal standpoint an observer in a balloon could telephone to the deck any signals or movements displayed ashore, or could, by signal flags, or the wig-wag, communicate with other vessels of the fleet at distances much greater than could the ship itself.

For night signaling, as hereafter described, the balloon offers several valuable methods. Balloons for French naval purposes are made of Pongee silk, with several coats of varnish. They are spherical in form, and have a cubical contents of about 320 cubic meters, with a diameter of 8.5 meters. They carry a wicker basket and a steel cable with a telephone wire in the heart. [English military balloons have cables $\frac{3}{4}$ in. in circumference; breaking strain, 1 ton; weight, 10 oz. per foot. The English telephone is a patent and does not require a battery.] They are filled with hydrogen gas, which is stowed in steel cylinders holding four cubic meters of hydrogen, under a pressure of 120 atmospheres. A tube filled weighs 30 kilogrammes. [English military balloons, hydrogen tubes, 70 lbs., 120 cwt. gas.] The sea anchor consists of a large water-tight bag, stiffened

above and kept open by an iron hoop to which the anchor line is attached by means of a linen band. In the bottom of the bag is a valve which can be opened from the car of the balloon by means of a cord. The balloon is usually anchored with 40 or 50 meters of line. The weight of the water in the bag prevents the balloon rising, and keeps it captive unless the valve is opened to free it. Ballooning, except by experienced observers, offers little for an immense outlay of money, time and storage space. Wind is the great enemy of the balloon, and sea-sickness, escaping gas, excitement and inexperience are apt to neutralize most efforts, unless a good deal of practice is had in time of peace. Accidents are not infrequent, and the expense is great, but at critical times they fill an important place.

Distant Day Visual Signaling.

The French use, as their distant code, large flags and a black ball or shape. Form of flag and not color is what counts. The code is as follows:



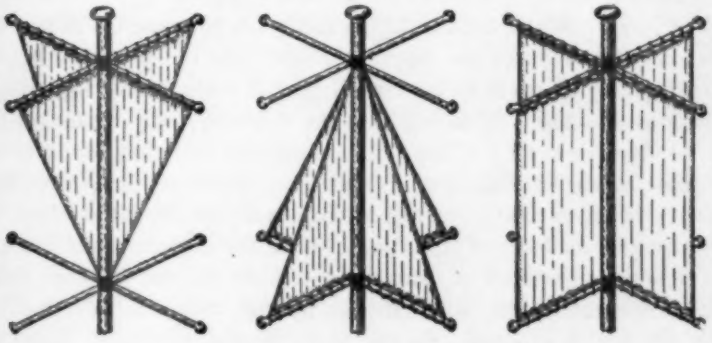
(The code calls are hoists of three elements).

French ships, in communicating with distant semaphore stations, use a cone in place of a ball. In communicating with one another they use the ball, but *can* use the semaphore code.

The International code of distant signals is as follows: There are three symbols, (1) a ball, (2) square or rectangular flag, and (3) a triangular pennant. The alphabetical characters have each three symbols. For instance, B.

With the coast semaphore, used by all nations by international agreement, an arm pointing downward represents a pennant; an arm horizontal, a ball; and an arm upwards, a flag. The disc on top at horizontal is the answering signal, and the disc vertical indicates that distant signals of the International code are being used.

In the British squadron manœuvres of 1891 the collapsing drum issued for service, as described, was found too small for distant day visual signaling. Aboard different ships different devices were tried. On some vessels this drum was used in conjunction with large national flags folded as pennants or as narrow flags, some 22 feet long and about 4 feet broad. With these some prearranged code was used. The difficulty was that the flags did not show except in certain directions, being thick and only held out in a stiff breeze, and then were only visible in certain positions. On other vessels immense collapsing drums were built of timbers and canvas, which required the entire watch on deck to hoist and collapse, using the Morse code. The general drift of all the experimenting was that it is impossible to communicate accurately or with any satisfaction at greater distances than those at which shapes of about 6 feet in height are plainly visible. In other words, shapes larger than 6 feet are too difficult to work and collapse in any kind of a breeze. The question is yet in an experimental stage. It has been proposed that sails be used—for instance, as in Figs. *A*, *B*, and *C*—to transmit the Myer or Continental Morse code. Fig. *A*, with the heads hauled



A B C

out, would, for instance, represent a 1 or a dot; Fig. *B* a 2 or a dash; and Fig. *C* a 3 or a "front." Of course the sketch is only a rough outline, and such a scheme appears fanciful and unseamanlike. Consider, however, with a fleet undertaking actual operations, how necessary it must be at times to communicate with the scouts or with vessels at a distance. Some means must be devised. However much we may respect the traditions of the service, we all know that most of the spars in such ships as the Chicago and

Newark would go ashore in time of war. In ships which are now building we ought to design the spars with due regard to this vital question of signaling—not, of course, to rig such an apparatus as shown in Figs. *A*, *B* and *C*, which would simply be used in an emergency and rigged with the resources on board, but to seriously get rid of top hamper, to consider questions of all-around visibility of signals, and to consult the demands of modern conditions in general. As has been said, the question of distant day signaling is in the experimental stage. Nothing satisfactory has emerged from it all. The chief defect which is likely to develop itself in some such system of shapes as proposed by the writer is that it will probably be found that refraction will distort the shapes at long distances and render distinction between them a matter of considerable uncertainty. Any such defect is, of course, fatal to distant signaling. Experiment can alone settle these points.

Night Visual Signaling.

The utilization of the electric light has added vastly to the rapidity and range of night signaling for squadron purposes. Night increases the value of color as an element in signaling, and destroys that of form. With powerful lights and with increased altitude to overcome the effects of the dip of the horizon, the range of night signaling may be made to far exceed that of distant day signaling.

Wig-wag.—Night signaling with the wig-wag code by means of a torch finds now only a limited application, and that for special purposes, as the introduction of some such system as the Ardois has practically superseded it, owing to the advantage the latter offers in rapidity and accuracy of signaling. With the electric apparatus all the elements of a letter or character are made in one display, and, being answered by the same display by the receiver, mistakes in receiving are eliminated. In the army several improved types of torches for night wig-wag have come into use, and have also been adopted in the navy. With the electric light, however, an incandescent lamp on a staff offers considerable advantages over the torch, especially in windy weather. In transmitting the wig-wag by night, a lantern is placed at the feet of the sender to mark his position.

Semaphore.—Experiments have been made in the British navy, as previously stated, with several devices for lighting up the sema-

phore arms. One plan has been to paint the arms white and throw on them a reflected light from a group of incandescent lamps. A semaphore for night work has also been tested, in which the arms carry a number of incandescent lamps to outline their positions. Neither plan is regarded as entirely successful, and the winker light is generally relied on for night squadron signaling.

Winker or Flash Lights.—In both the British and Italian navies electric lamps are used with some device or shutter to flash dots and dashes, using the Continental Morse code. To get increased range of signaling, lamps of fifty and a hundred candle-power have been experimented with. The great defect has been found to be that with such high-powered lamps the carbon does not flash or die down quickly enough. This consumes time, as the dots and dashes have to be made much longer than in telegraphy, but the Italians have overcome the difficulty somewhat by using a globe lantern in which a nest or group of six or eight 12 or 16 c. p. lamps are used, all worked with one key in the same circuit. These are mounted on the trucks of torpedo-boats and very high on other vessels. The smaller carbon filaments are found to work successfully, and the fixing of the lamps rigidly on the trucks of smaller vessels has been found to be a great advanage in a sea way. In the British service one device to overcome the question of the slowness of the carbon has been to have a multifiber filament, that is to say, one made up of a bundle of smaller ones. This has reduced the defect very considerably. Another device has been to keep the lamp burning and operate shades to obscure the light. On some vessels this shade is simply a bag fitting over the lamp, operated by halliards on deck, which are attached to a lever which is worked up and down. A very successful device, invented by Captain Scott, R. N., has been tried but not adopted. It consists of a high-powered lamp, surrounded by a number of vertical shutters worked by an electro-magnet and a spring. The shutters revolve through 90° when a current is sent through the electro-magnets by the signal key, and the light is exposed all around until the current is broken, when a spring snaps the shutters to and obscures the light. The lamp has a resistance in it which is thrown in when the shutters are in an obscuring position, so that the lamp does not burn at full power. This saves wear on the filament. In our navy no regular device of this kind has been adopted, although some experimenting was done on the

Trenton and since carried on in the newer ships. As long as we have the American Morse as the service code, no serious attempt is likely to be made to perfect one. The Ardois or some such system is so much more rapid and certain than winker lights that the latter can only have a limited application. In a series of experiments off Montevideo in March, 1892, it is recorded that a 32 c. p. white light, at the main truck of the Bennington, was visible on a clear night over eight nautical miles, which shows the value of a truck lantern for distant wig-wag, where the lower lights of the Ardois would be hull down.

Coston Signals.—In the absence of any better system the Coston lights were at one time widely used for naval and commercial purposes. Recently an improved percussion arrangement was added to these signals, and the Navy Department was prevailed upon to order a test. In March, 1892, a board was appointed on the South Atlantic station to make a series of trials of the Coston, Ardois and Very systems on board the Chicago and Bennington. The night selected was a dark, star-light one, with atmosphere unusually clear and free from haze or mist near the horizon. Of 50 Coston lights burned, at distances varying from three to eight miles, and at a mean height of 32½ feet on each ship above the water, 29 were correctly read, 20 incorrectly read, and 1 was not seen. Eight miles was the limit at which the dip began to interfere seriously. Nine signals were marked doubtful on account of the confusion of white and green, as the shade of difference was very slight. A blue light was read as green. The signals averaged 30 seconds in burning each color of which it was composed. The finding of the board was that "The Improved Coston Night Signals are entirely unsuited for naval use. Forty-two per cent. of them failed to be correctly read, the color distinction being very poor. This is a cardinal defect, and would alone be sufficient to cause the rejection of a signal for military purposes; but in addition thereto the Coston signals show the following minor objections:

1. They require a long time to burn, and signaling with them would be much slower than with the Very signals.

2. They make much dirt, the products of combustion flying about the deck and defacing paint work.

3. They make a blinding glare, rendering it impossible for those standing about to see anything inside or outside of the ship.

4. They are made only by the manufacturers from whom renewed supplies must be ordered, and cannot, like the Very's, be reloaded on board ship."

Electric Night Signaling Apparatus.—An experimental apparatus and night code was used in the North Atlantic squadron in the summer of 1890 and until the latter part of 1891, the invention of Lieut. H. McL. P. Huse, U. S. Navy. It was intended for night signals with colored lights, and day signals with collapsing shapes; for red light using a cone, and for green light a cylinder. The following is the description as issued for trial:

In this system, one red and one green light are necessary. They must be placed sufficiently far apart that each may be distinctly visible.

The Very code for night signals may be used in connection with any of the signal books, or a message may be spelled out by the American Morse code.

The *general call* is made by exposing a green light until it is answered by all the vessels within signaling distance.

The *special call* is made by signaling the initial letter of the vessel called until answered.

The answer to a call, or I understand, is made by showing a red light.

The repeat, or, I do not understand, is made by showing a green light.

NOTE—This change is made to preclude any mistake as to what vessel is making the call. If the answering were green, attention might be directed to an answering vessel instead of to the calling vessel.

Attention may be drawn by firing a red Very signal.

The lights will be made in succession, according to the Very code accompanying this circular.

Use telegraphic book: Show both lights together twice, followed by the designator G G R G.

NOTE.—Lights should be exposed about two seconds and be separated by an interval of about two seconds. It is not intended that measured time elements shall enter. Times of exposure and of darkness are given simply as a guide. A little practice will enable a signalman to make his lights and intervals regular; this is all that is necessary.

Signals are separated by the designator.

The completion of a signal is indicated by making two designators.

Use General Signal Book, make three doubles, $\begin{matrix} R \\ G \end{matrix}\!\!\left.\right\} \begin{matrix} R \\ G \end{matrix}\!\!\left.\right\} \begin{matrix} R \\ G \end{matrix}\!\!\left.\right\}$.

Use Morse code. Expose the red continuously; while green is shown intermittently twice; then proceed with the message, a dash being green and a dot red. Words are separated by a double.

Two dots separated by a space are made thus: the red is exposed continuously for about six seconds; during the third and fourth seconds, the green is also exposed.

"Error, I have made." With any code, expose the green continuously while the red is shown intermittently three times. If using the Very code, begin again with the designator preceding the error. If using the Morse code, begin with the last word correctly sent.

To break, show a green.

To start after breaking, show a red.

Instead of the red and green lights, any other recognized means may be used in answering, as a torch, or two lanterns, or Very signals. In using Very signals for this purpose, the signals fired must conform in color with the lights called for.

The objections to this system are that it uses a green transmitted light, it is very slow, and with such apparatus as the Sellner, Ardois, or Kasolowski, it compares most unfavorably both in rapidity and certainty of signaling.

A brief discussion of the theoretical requirements of an electrical night signal apparatus will throw much light upon the lines along which these modern systems have been developed. In the first place, *as to colors*: Three have been more or less used, green, red and white. Green has now been entirely discarded. As a transmitted light it lacks visibility and is confused with white. Red and white have come into general use, but in the most recent apparatus a pulsating white light has been substituted for the red. In a French experimental apparatus, as previously stated, both red and white pulsating lights have been introduced. In the face of the exhaustive experiments abroad we are compelled to accept the dictum that a white light is visible further than a red (which also conforms to theory) and that a pulsating white light is visible further than a fixed white. *As to types of lanterns used:* The range of visibility of a light at sea in clear weather depends upon the height of the lamp above the water, its candle power, and the character of the lense or *reflector* used. Some apparatus limit the visibility to a certain direction by putting in shades and reflectors. The requirements of a lantern are as follows:

1. It should be double, and provided with a diaphragm to exclude the light of one lamp from the other half of the lantern.

2. But one lamp in each lantern should be displayed.

3. The lantern should be air-tight to exclude moisture and powder gases which erode the terminals and contacts.

4. It should be fitted with a Fresnel lense, which concentrates the rays in a horizontal plane.

5. It should give visibility all around the horizon.

6. It should be so suspended as to always take a vertical position in order that the rays of light may be thrown out horizontally, but not so freely as to strain the leading wires or chafe the main cable.

7. It should be simple in construction and easily opened to replace a lamp burnt out.

As to candle power of the lamps: We generally use 32 c. p., which gives excellent results. The French use 30 c. p., and the Italians 25 c. p. High power, of course, gives increased visibility and distinctness. *As to cable:* In the wiring of signal lamps the leads are generally made up into a cable and protected from chafe by a covering. A common return is generally used and separate leads to each lamp. In connecting with the signal box or key-board the attachment should be made by a coupling and not by separate wires to separate binding posts. The coupling facilitates testing out the circuits. The cable should be more or less permanently suspended from a yard-arm or working gaff, and secured at intervals to a taut guy or backstay to take its weight. In the Italian navy the cable is sometimes suspended to the fore and aft horizontal stay between the military mastheads. There should be a switch in the common return, working automatically, so that the current will not be thrown on till after the contacts are made for signaling. This prevents sparking, and consequently burring and wearing of contacts in the signal box. *As to signal box or key board:* Contacts which are made against the face of a spring are not reliable, as the springs weaken in service. The box should be water-tight, and the movement of the key arm should be as simple as possible to give speed in signaling. Boxes are sometimes set at an angle to facilitate operating the lever or arm. The face of the disc should be marked opposite each sector as to the display of lights and the significance thereof. *As to the number of lights* in the permanent hoist: The French at one time with the De Meritens apparatus, used eleven. The two upper and the two lower lights were red, and the intermediate were white. On account of the blending of the lights, owing to their close spacing, the range of visibility was very limited. This system was superseded by one of four single lamps. Experiments are now being conducted with four double lanterns. The Italians and Austrians have adopted four; Spain is experimenting with four; and Germany has adopted

three (all double lanterns). The British Government has ordered a three-lamp apparatus for experiment, but the system meets with but little favor. We have practically adopted a five double-lantern hoist, in that we have committed ourselves by contract in the ships now building to the use of the Ardois or some similar apparatus. The question involved is this: The board organized on the South Atlantic Station to test the Ardois and other systems report that "Under ordinary circumstances the Ardois signals can be read with certainty at a distance of four miles. By actual experiment the Ardois signals of the Chicago were read from the Bennington five miles distant with night glasses, the lights being distinct both as to number and color:" But the Chicago lights are 32 c. p., spaced 5 meters, or 16 feet 5 inches, apart, and the lower lantern is not less than 35 feet above the water line. We fail, however, to realize that our more recent ships have no such spars, and that a modern squadron is made up of all sorts and conditions of craft. The auxiliary vessels of a fleet, the despatch vessels, the torpedo gunboats, the torpedo-boats and repair vessels, the swift commerce destroyers, and also the low free-board battle-ships offer no such hoist for signal lanterns as will allow the upper lantern a height of 100 feet above the water line. If our service code requires it, and if we want five lanterns, we must, of course, spar all our vessels with some regard to the requirements of space between lanterns. With five lanterns, the scouts of a fleet, the vessels on which devolve the reconnaisance, and on which depend the rapid and accurate transmission of important intelligence to the main body, will be just the ones whose hoist of lights would be most limited in space and hence in visibility. With four lanterns instead of five, the maximum distance would be greatly increased.

Devices Used Abroad for Night Signaling.

Berg's.—This has been experimented with in the German navy. It consists of three oil or electric lanterns with a white shade fixed in front of them, and with a movable red and a movable green shade so operated by electro-magnets as to throw at will a white, red, or green light. Where electric lights are used, a small hand dynamo gives the current. With this apparatus twenty-seven three-light signals can be made. The defects are that it lacks range; it

gives visibility only in one direction; and it uses the green transmitted light, which is limited in visibility and leads to confusion with the white.

Conz.—This apparatus is patented in England, the United States and Germany. It is a German invention. The last named government has ordered 100 sets for installation, which practically amounts to adopting the system. Three double lanterns are used with the colors red and white. The white light has an opal shade, but no device or lense is used for intensifying the power of the lamps. Resistances are used to keep the required current constant. Fourteen characters can be transmitted by this apparatus.

De Meritens.—This is used in the French navy. It has eleven lamps on a backstay, each lamp having a separate key. There is a tell-tale box to show what lights are on. The two upper and two lower lights are red, and the seven intermediate are white. This device lacks range, and is in a fair way to be superseded.

Ducretet.—This was used in the French navy. It consists of four single lanterns transmitting fifteen different signals, showing, however, only in one direction. It is out of date. The Sautter and Harle apparatus uses the same code as the Ducretet but is simpler in design, and has a switch in the circuit to prevent sparking.

French Experimental.—This is being tried in the French Mediterranean fleet. It consists of four double lanterns, half red and half white; it has eight separate leads and a common return; and it uses a pulsating or fixed current at will. The pulsations are given by a hand key. It uses a four-element code: (1) a fixed red, (2) a pulsating red, (3) a fixed white, and (4), a pulsating white. Each display has four lights. If less are shown, an error is evident and the signal is disregarded. This apparatus is quite up to date and gives a very flexible code.

Kasolowski.—This apparatus is used in the Italian navy. It has four double lamps of 25 c. p., and for torpedo-boats has a space of 5 feet between lanterns. Each lantern is double, the lamps being carried in a bronze frame which is held rigid between two guys which are slung from a gaff or yard-arm and set up taut on deck. For vessels not provided with an incandescent plant a hand dynamo operates the circuit.

Sellner.—This is unquestionably the simplest and most widely used night apparatus yet invented. In one form or another it is

found in both the Austrian and Italian navies, as it is practically the same as the Kasolowski, and similar to that used in the German navy. The latest model is, however, a great improvement on the older forms. One of these was purchased by our government and mounted on board the U. S. flagship Chicago in December, 1891, for trial in comparison with the Ardois. As it was fitted with four double lanterns, which is largely the custom abroad, instead of five, it was for convenience marked with the characters of the International code, using a few special and code calls. No lenses are used in this type in the lanterns, but instead plain red and ground white glass shades are fitted. With the apparatus sent two screens or blinds were attached to each lantern so as to make the display in certain directions, this being the custom in the Austrian navy. As these blinds can be easily and readily removed, they form no real part of the apparatus unless desired. They are simply prescribed by the Austrian navai authorities in their contracts. There is a device fitted to the transmitter or key box by which small resistance lamps may be thrown in or out of circuit to keep the current constant. These are intended for use with a hand-power dynamo, but can also be used with a regular dynamo as a tell-tale showing the signal displayed. The official report was made by Lieut. S. A. Staunton, U. S. Navy, as to the comparative merits of the Sellner and Ardois apparatus, and he objected to the Sellner as follows: 1st, to the marking of the instrument with the International code as not giving a fair test with the Ardois, which uses a full alphabet; 2d, to there not being thirty displays provided for, which is the maximum for four lights; 3d, to the use of the screens or blinds, as destroying the greatest value of the apparatus, viz., all around visibility; 4th, to the lanterns not being provided with lenses for strengthening the lights; 5th, to the awkward motion of the switch or lever on the transmitter for signaling; 6th, to the use of the resistance lamps as adding complications; 7th, to the cable not having a coupling for ready detachment for testing out the circuits; and 8th, that in point of general workmanship it is inferior to the Ardois. This represents, of course, an individual opinion. Against it must be set the fact that one of our best authorities in naval matters pronounces the Sellner apparatus the simplest and most endurable in service of all those in use in the various navies. It may not compare in workmanship, but it costs $700, delivered in this country, as compared

with $1100 for the Ardois. The transmitter can easily be arranged for displaying thirty characters, and, using the Myer, Very, or similar code, can transmit an alphabet or numeral code without difficulty. Lieut. Sellner, of the Austrian navy, the inventor of the apparatus, replies to the remaining objections of Lieut. Staunton, as follows: The blinds form no necessary part of the apparatus. The signal switch or lever is purposely made of not too easy manipulation to assure the attention of the operator. After numerous trials the use of lenses with the lanterns was abandoned on the score that such arrangement failed to increase the range of the signal. This range depends upon the distance the lanterns are spread from the others in their hoist, and if this distance is 4 meters, the signals are well visible for about 5 miles. Where the intensity of the incandescent lamps reaches 32 candle power there is no use of increasing this intensity, since no longer range of the signal is thereby attained. The use of a coupling in the cable is objectionable as introducing a break in the conductor, and hence an element of unreliability. The principle of plug contacts in the transmitter is where this apparatus is superior to any other yet devised. In large ships there will always be two complete night signaling apparatus, thus avoiding difficulties arising from masking of lights, failure of lamps, etc. These arguments on the Sellner apparatus are here given in detail to show that this question is not to be settled off hand. The original Ardois apparatus has many faults, which in new designs in this country are being remedied. The field is an open one. The problem is merely to display certain combinations of lights. Experience abroad cannot be ignored. Where we are making a mistake in our navy is, on the one hand, in not fully recognizing the immense value of such apparatus, and on the other, binding ourselves to the use of five lanterns instead of four, and to the use of an extremely objectionable and unnecessary code.

Massari.—This is a new Italian apparatus on trial in the Italian navy, similar in some ways but simpler than the Kasolowski. The transmitter or key box has a hinged lever which lifts and sets down at the proper sector, making contact against the face of a spring, which is an objectionable feature. A Morse printing apparatus receives the signal made on slip of paper. The same types of lanterns and the same code is used as in the Kasolowski.

Ardois.—This apparatus has been adopted in our navy and, in

all, fourteen sets have been ordered from France. For the ships building at navy-yards the contracts are let in this country, and many improvements are being introduced by the contractors, and by suggestions from the office of Electric Lighting, Bureau of Equipment. The foreign type, as mounted first on the Chicago for trial, was described by the writer in No. 58, Proceedings Naval Institute, 1891. The new features are the lantern and key box or transmitter. The new lantern is air-tight and water-tight. A special feature is the readiness with which a burnt-out lamp may be replaced. Another feature is in the lead of the wires through the center of the top and bottom, enabling the lamp to be suspended at its middle point to swing freely and remain vertical, thus insuring the transmission of light in the horizontal plane. If a lantern with a Fresnel lense is canted, the light is not visible as far as if the lantern is vertical, and hence the rays of light horizontal. A further feature of the mount of the lanterns is the use of two parallel stays to which the lanterns are secured. The contacts in the key box are the same as in the old, but the box is water-tight. There are sixty-four sectors, but tbe marks radiate from the center, and the lever works around the circumference of the box. The pistons which make contact with the bosses or stops are beveled and rounded to give good contacts. It is, however, a grave mistake to use the so-called Ardois alphabet. It is inferior in every particular, save one, to the old Myer code. As to the folly of adopting five lanterns instead of four, it need only be pointed out that when we go on paying $1000 a piece for such apparatus for vessels like the Vesuvius that cannot mount five lanterns, and also for the short-masted new ships (even like the Philadelphia), and when we are committing ourselves indefinitely to the use of codes that violate every principle of signaling, one voice of protest is not enough to arouse the least official interest in the subject. When, however, at our own invitation, we assemble a fleet in our harbors next May, we will make an exhibition as to signals that will give us no reason to congratulate ourselves. The Ardois apparatus is an excellent one; but the field is an open one, and we want the best. There is, however, no excuse for the existence of the Ardois code, and there is no hope of the Myer code being re-adopted.

Distant Night Visual Signaling.

As previously stated, night destroys the value of form and increases that of color. To increase the range of night signaling, we must overcome the dip of the horizon, and must increase the power of the lights used. All around visibility is a prime requisite, and the conformity of the code with that used in squadron cruising is very desirable.

By balloon.—Balloons give increased altitude, and hence increase the range of signaling. Mr. Eric Stuart's signaling balloon, tried recently at Fulham, England, is made of varnished cambric, and is therefore translucent. It is 18 ft. in diameter, has a capacity of 3200 cub. ft., and is controlled by a cable 500 ft. long, weighing 35½ pounds. The balloon contains six incandescent lamps, each of 10 candle-power, and the electricity is supplied from 26 accumulators by means of wires running up the cable. The signaling key has carbon contacts. England and Belgium have purchased for army purposes the Bruce Electric War Balloon, which is made of a translucent material, and is operated similarly to the above. At Heligoland, in 1891, a German squadron used, with great success, a captive balloon for distant and squadron night signaling. Incandescent lamps attached to the underneath side of the car were operated by a key using the Morse code. Arc lights were also used, and, besides lighting up the surrounding harbor and shore line, the beam was used for distant signaling.

Search lights.—The beam of search lights thrown on low, heavy banks of clouds offers a feasible and useful method of distant night signaling. With vessels hull down and practically below the horizon to each other, it is the only method possibly available. Search lights are fitted with shutters for this purpose, and such signaling occupies a definite place in any scheme of night signaling. In August, 1892, a search light used on Mt. Washington, N. H., transmitted a message which was read on the clouds overhead at Portland, Me., 85 miles distant. The beam was thrown upwards at an angle of 45°, and it has been estimated that to reach Portland it must have been 110 miles long, and was reflected from clouds 80 miles overhead in the last named city.

Very's signals.—Red and green stars are projected from a pistol to a height of 100 feet or more. This height is limited by the character of the stars, which cannot be made tough enough to stand the

increased velocity and pressure of larger charges. Exhaustive trials have been conducted under the supervision of Lieut. R. T. Mulligan, U. S. Navy, whose report has not yet been adopted as to the recommendations made. As to colors, all shade into either red or white at any distance, so that only two are practicable. Green was recommended and is used, but white is quite as good. All cartridges deteriorate in service. The original bracket code has not been formally abolished. Lieut. Mulligan's four-element code is issued experimentally, and is very successful. The firing pistol is still issued. It is inferior to the short double-barrelled shot guns recommended. The green star should be changed to a white. This is not particularly important, except for the sake of uniformity with the Ardois. It is not feasible to transmit the alphabet by the Very code, as it takes too many cartridges. In the experiments made by the board of officers in the South Atlantic, previously referred to, 13.7 nautical miles must be taken as the practical limit of the present Very outfits furnished ships. As eight miles is given as the limit of deck signals, the five and seven-tenths miles of further visibility must be due to the projected height of the stars. The official report of the board states that "The Very's signal meets all requirements for long distances. It is slow but certain, the color distinction being excellent; and with the lights grouped in fours to avoid bracketing, repetitions are seldom necessary. It is not suited for tactical signals because it is slow, and because it is not absolutely certain that the signal has been correctly read, and an error in tactical signals may produce collision. Certainty of correct transmission can only be assured in a night signal by repeating each display back to the sender. The scope of the Very is limited by the number of cartridges supplied. A long telegraphic signal would quickly exhaust the allowance. These cartridges can be reloaded on board ship, red and green stars being supplied for the purpose."

This excellent system of signals is capable of much improvement in detail. With brass reloading cartridge cases, excellent pistols or guns, and a four-element code, we would have the best distant night method in the world. The French use Coston signals, but supplement it by a code of lanterns hoisted in groups similar to flag signaling.

III.—Phonetic Signaling.

In a fog visual signals are, of course, useless. The only resort is to sound, using some phonetic code transmitted by drum, bell, gong, horn, bugle, whistle, siren, or gun-fire.

Squadron Phonetic Signaling.

Fog-whistle. — The steam whistles of vessels-of-war should be fitted with elbows in their pipes and drain-cocks for running off the condensed steam. Hand levers should be fitted to take the place of whistle cords. These should be capable of unshipping when not in use. Fog-whistle drills should be instituted in squadrons to perfect officers and men in the use of a code. Canvas screens should be put up around those on the bridge in charge, and at the wheel, and the conditions should be as nearly as possible those of a fog. Such drills are most important and valuable. At present in our navy we have no authorized method of transmitting our service code on the fog-whistle. As this American Morse code is dangerous to navigation, it is probably just as well that no method is prescribed. All vessels should be fitted with audiphones or other mechanical means of locating the direction of sounds in a fog. The importance of a squadron keeping in touch in foggy weather, and the danger thereof, unless an efficient phonetic code and apparatus are used, would seem to warrant some official interest in the matter. The French flash lantern and fog-whistle code is as follows:

1.	-	6.	—
2.	- -	7.	- —
3.	- - -	8.	— -
4.	- - - -	9.	- - —
5.	- - - - -	0.	— - -

Using a bell, gong or drum, a dot is one sound and a dash two successive sounds. The superiority of a four-element Myer code over this or any other dot dash numeral code is most apparent.

Distant Phonetic Signaling.

Rapid fire guns offer a good means of transmitting a code at a distance in a fog. It is best to limit the code to numerals, although with an interval character like 2 2 1 2 it is possible to transmit an alphabet. A numeral code would, with a telegraphic dictionary,

effect the same purpose. The French officially prescribe the above code for gun-fire purposes, using two successive fires for a dash.

Conclusion.

In discussing the various methods of signaling here presented, nothing has been said of the relation of signaling to tactics. We have discussed methods only, and have endeavored to simply show wherein and in what measure naval signaling differs from army signaling. Tactics demand of methods of communication three things: reliability, simplicity and rapidity.

Reliability involves mechanical perfection as to not failing at critical times, and certainty as to the message being received as sent. This is usually insured only by repeating back, which is, however, at the expense of rapidity.

Simplicity implies the use of a code of few elements covering a wide range of usefulness. The fewer the elements, the slower the signaling, but the greater the range of visibility, or the more reliable the signal as to distinctness.

Rapidity is, therefore, limited by the consideration of simplicity, and increased by mechanical perfection and reliability, which last restricts the too rapid methods of signaling. Tactics demand rapidity, but the crowning virtue is reliability.

Therefore, *that method is best which is most reliable and which is as simple and rapid as is consistent with absolute reliability.*

The question of interior communication on board ship affects tactics in the extent to which the whole ship is subordinated as a unit to the guiding mind which is working out the problem before it. The accurate signaling of the range, the constant touch necessary between the bridge and the engine room as to speed and keeping position, the net-work of communications to the torpedo tubes, batteries, ammunition supplies, water-tight subdivisions—all this is a problem in itself, but it is entirely a matter of methods and not of codes.

We must bear in mind that in our own service we are in a transition stage, so that any apparent criticism of methods is really only the application of experience to the modernizing of our methods. From a tactical standpoint the signal books need a general revision, and in view of the possible use and wide range of alphabetical characters (as in the international code), the index for entering the

books and each signal itself should be given both as a numeral and as a group of letters. As to the use of action or battle signals, there are many who hold that in a general action no signals can be read or will be heeded. Single flags are, however, advocated for battle signals, and these should have an alphabetical significance as in the international code. This would enable a vessel to transmit the signal by her fog whistle when obscured by the smoke of battle. It may be readily imagined that some sort of communication between vessels for tactical purposes would be needed in battle under some circumstances, and if flags and shapes are obscured, the fog-whistle offers another means. If shapes are to take the place of flags, then the battle signals should consist of simple characters capable of display in one hoist.

We have in our navy three service codes: (1) a numeral flag code of ten elements; (2) the American Morse alphabet and numeral code, and (3) the original Very three-element or bracket code. We have, besides, three experimental codes in use in the North Atlantic squadron: (1) a new flag numeral code, using yellow in several flags in place of white; (2) the so-called Ardois alphabet and numeral code, and (3) the four-element Very code (originally proposed by Lieut. R. T. Mulligan, U. S. navy). There is as yet no official order prescribing the method of using the American Morse code on the fog-whistle or by gun-fire. Our general signal book contains almost no recent additions of new signals demanded by modern conditions, and is filled with many that are out of date. Surely there are enough questions awaiting some decision or official action to warrant the appointment of a board to consider what is to be done. The new flags possess the merit of great visibility and distinctness, but it should be definitely settled as to three-flag hoists being the *maximum*, and as to battle or action signals being one-flag hoists. Shapes should be experimented with; the Very four-element code should replace the old bracket one; homing pigeons should be regularly adopted as a means of communication; and, above all, the American Morse code should be withdrawn from active service. We have no method of distant day signaling, and distant phonetic signaling is only vaguely alluded to in the Revised Instructions in Signaling, which are issued experimentally.

The old Myer code is the most nearly perfect one in existence. It has been shown, however, that certain practical considerations as

to four lights in a permanent hoist have made it desirable to limit the group of elements in the numeral code to four. Happily, the four-element Very night code offers just the numeral code needed to take the place of the one of five elements used in the old Myer. As applied with the Myer alphabet, it gives us thirty characters in what we may call the Myer-Very code or the Modified Myer code. These thirty characters are capable of transmitting any possible message under every possible condition of service. It is a perfectly well recognized principle of modern signaling that one group of elements (that is, a character) must be allowed more than one meaning or signification. For instance, in the English semaphore code of three elements, the ten numerals duplicate ten letters of the alphabet. In our general flag code, by the use of such flags as the geographical or telegraph, we can give to a hoist of flags several different significations; also, in our wig-wag code, as specified in the instructions in the General Signal Book, we may, by the use of such code calls as G. L. U. or T. D. U., etc., give a special meaning to any signal used.

We may, however, in place of the Myer code use the Continental Morse in the same way, either by calling the dot a 1 and the dash a 2, or by changing the Very numerals to dot and dash, as shown on page 448. This would give us a modified Continental Morse code of thirty characters.

If there is any value in theoretical considerations; if the experience of foreign navies is in any way a guide to us; if what has been here outlined is correct in principle, and of the least practical value, then we should adopt the Modified Myer code for all purposes of signaling. We can use its thirty characters as a wig-wag code for hand flag, torch, winker light, or search light; as a squadron distant code with shapes on a signal mast; as a night code with four double lanterns in a permanent hoist; with the Very stars for a distant night code, and with the fog-whistle and gun-fire in a fog. Abolishing the musical signals in the infantry and artillery instructions, the letters of this code transmitted by bugle could be used, and much confusion and misunderstanding avoided in brigade operations on shore. With only thirty characters to learn for *all* purposes, signaling in general would be much simplified. The same remarks apply to the present night speed-signals authorized by the Fleet Drill Book. With a double lantern (half white and half red,

as in the Ardois) for squadron cruising purposes, on the truck of all our vessels-of-war, there would be no need for using the elaborate yard-arm, truck, and stern lights now carried. No matter how well drilled the look-outs may be, or what rare presence of mind an officer-of-the-deck may develop in any emergency, it is too much to expect that the speed-signals now in use can be properly made in the excitement of a moment. Assume that in steaming in open column (which is the safest formation for night cruising) the leading vessel suddenly develops a danger close aboard. The helm must be put over; both engines reversed or stopped; the steam whistle sounded as to helm signal; if the danger is very imminent, the water-tight door signal must be made; the two white lanterns must be hauled down from the yard arm, and the red light displayed astern. If the halliards jamb, or if the signal is imperfectly made and the vessel next astern rams the leading vessel, then the officer-of-the-deck of the last named vessel is *responsible* for the signal not being properly made, and yet he is not in a position to control the signals in an emergency and keep his attention on the danger ahead. The lights as now authorized are a real source of danger to the vessel carrying them, and they confuse merchant vessels, as every one will testify from experience. In time of war, no squadron is going to advertise itself with *any* lights. It would, therefore, be best in time of peace to practice cruising as would be done in time of war. No permanent display of lights is really needed. Vessels can keep in touch without it, and should be required to do so. A board of officers in the Squadron of Evolution, of which Captain Philip, U. S. Navy, was senior member, submitted a report to the Commander-in-Chief in November, 1891, on the subject of speed signals, as follows:

"1. With regard to day speed-signals in squadron, it would be in the direction of simplicity to abolish the pennant and use only a ball of an improved type, which ball should have four positions. Up at yard-arm, 'going ahead at full speed last indicated by signal;' half-way down, 'backing or going astern;' just above rail, 'steerage way or slow.' Out of sight, 'stopped.' The ball should be larger and heavier than that now used. It could be pierced through one axis by a steel tube working on a wire back stay, the tube working as a traveler. It would come *down* of its own weight. The lower end of the back-stay could be shifted and

set up when the yard was braced (if the yard is movable). The question is the usefulness of the pennant. It is supposed to show relative speed, but it is a deceptive and inadequate device for accomplishing a purpose which can better be accomplished by signaling the exact speed. In the manœuvres off Bar Harbor this summer (1891), if the real speed had been signaled, then there would have been no doubt as to the 'fast speed' intended. The pennant required one or two men to run it. On a bridge of a vessel like the Concord it adds extra men. It can easily be dispensed with.

"2. With regard to night speed-signals, no lights other than the international lights should be permanently displayed. Each vessel should have in position, astern, a red globed lantern containing a lamp, controlled by the officer-of-the-deck from a switch on the bridge. This light should be displayed only in the emergency of stopping and backing. It should signify to the vessels astern 'look out for yourselves!'

"The yard-arm speed-lights (white) are a source of danger, on account of the liability of the halliards jamming, and they do not adequately indicate relative speed. They throw a glare on the bridge, they confuse merchant ships, and require from two to four men to manipulate them quickly. In case of emergency they are one more complication for the officer-of-the-deck . . . The mast-head (truck) light is not useful, as at night the sextant is rarely used to judge distances . . . In time of war, ships would have to keep their position, and keep together without lights . . . (We recommend that) there be placed on the fore and main truck of each ship in commission a double lantern, similar to that used in the Ardois apparatus, and connect the lamps by wires with a key board. The white light should be used as a winker to transmit the Myer-Very code, using the red light for the 'front' to mark intervals between words and sentences and end of message. These lanterns are useful in case the Ardois or other apparatus is masked or out of order; they can never be masked; and they would be in position to use as a white or red truck-light for squadron purposes such as for guard ship, etc. . . .

"We recommend (in place of the white yard-arm lights), in case it is desired to signal, 'we are going ahead a little faster,' flash dots from the white light at the mast-head (truck). In case

a vessel slows down for any reason, flash long dashes with the white lantern which will indicate 'look out, we are slowing a little.' (The red lantern should be used similarly for stopping or backing.) The points aimed at are that (1) no permanent lights should be displayed other than the regular ones, and (2) all other speed and emergency signals should be under the immediate control of the officer-of-the-deck. This point is vital." (Oil lanterns should be kept at hand, lighted and ready for signaling in case of accident to electric plant or truck lantern.)

Let us take the Armored Cruiser New York and imagine her fitted with the latest appliances for signaling, and using the methods of signaling here advocated. She would have two military masts with signal topmasts, each fitted with a set of four collapsible shapes, one set for squadron cruising, about 2¾ ft. in diameter of discs, and 4½ ft. hoist, and the other, 4 ft. in diameter and 7 ft. hoist, for distant signaling. There would be halliards for international flags (since all ships are required to have them), and two signal yards, one on each mast, for hoisting flag signals (international) for such routine signals as might not seem to require the use and wear and tear on the shapes. There would be two sets of permanent hoists of four lanterns, one on each mast, on a stay from the mast-head, so as to show from the port or starboard bow, and from the starboard or port quarter. Each hoist should have its own key board and circuit. On the truck of each mast would be a double lantern (red and white) for a winker light and speed-signals. Each truck lantern would contain two groups of six 12 c. p. lamps, worked from a key on the flying bridge for the officer-of-the-deck and on the signal bridge for ordinary signaling. The steam whistle would be specially fitted with levers, cocks and drains for fog-whistling purposes, and there would be on the bridge an audiphone for locating the bearing of sound signals. Arrangements would be made for homing pigeons for use in squadron manœuvres to be utilized in time of war, and for Very's signals short barrelled shot-guns would be provided for projecting the stars. The signal men would be rated men, petty officers, ranking next after coxswains, and their assistants would be men or boys training to become quartermasters or signal men, receiving extra compensation for such service. They should all be required to know the American Morse code, so as to be able to communicate with army stations when necessary; but it would not be the code

used on board the New York or in the naval service. Thus equipped, this ship would be unquestionably better off in respect to signal code, apparatus and methods than any vessel afloat.

It would be too confusing to go into a detailed description of the method of using the Modified Myer code for all purposes of signaling. It will, however, concisely illustrate the simplicity of the scheme to give here a tabulated outline of it. Every detail is capable of ready explanation, and, while the synopsis in no way explains itself fully, the scheme is all there. It has been submitted officially and awaits the action of the Navy Department.

CODE CALLS.

1. A. S. U. Action or Battle signals use.
2. I. C. U. International code use.
3. T. D. U. Telegraphic dictionary use.
4. G. L. U. Geographical list use.
5. S. B. U. General Signal Book use.
6. F. D. U. Fleet Drill Book use.
7. C. A. U. Cipher "A" use.
8. G. B. U. Cipher "B" use, etc.
9. O.N.U. Ordinary numerals use.
10. C. S. U. Compass signals use.
11. V. N. U. Vessel's numbers use.
12. N. L. U. Navy list use.

THE MODIFIED MYER CODE ADAPTED TO ALL PURPOSES OF SIGNALING.

Character.	1 Wig-wag.	2 Night Signals. (Ardois.)	3 Special Signification.	4 Very's Code.	5 Proposed Very's Code.	6 Fog-whistle.	7 Gun-fire.	8 Shapes.
A	2 2	W W			Same as colums 3 and 4, excepting in the use of white for green to conform to column 2.	Same as columns 1 and 3. — The 1 of the Wig-wag is one toot. — The 2 is two toots. — The interval is one blast.	Same as columns 3 and 4 or 3 and 5. — The red is one gun-fire. — The green or white is two gun-fires.	Same as columns 1 and 3. — The 1 of the Wig-wag is a cylinder. — The 2 is a globe or a trapezoid of revolution.
B	2 1 1 2	W R R W	0	G R R G				
C	1 2 1	R W R						
D	2 2 2	W W W						
E	1 2	R W						
F	2 2 2 1	W W W R	4	G G G R				
G	2 2 1 1	W W R R	6	G G R R				
H	1 2 2	R W W						
I	1	R						
J	1 1 2 2	R R W W	5	R R G G				
K	2 1 2 1	W R W R	Negative	G R G R				
L	2 2 1	W W R						
M	1 2 2 1	R W W R	9	R G G R				
N	1 1	R R						
O	2 1	W R						
P	1 2 1 2	R W R W	Affirmative.	R G R G				
Q	1 2 1 1	R W R R	Interrog.	R G R R				
R	2 1 1	W R R						
S	2 1 2	W R W						
T	2	W						
U	1 1 2	R R W						
V	1 2 2 2	R W W W	7	R G G G				
W	1 1 2 1	R R W R	Annul	R R G R				
X	2 1 2 2	W R W W	Code call	G R G G (Numeral)				
Y	1 1 1	R R R						
Z	2 2 2 2	W W W W	2	G G G G				
Cornet.	1 1 1 1	R R R R	1	R R R R				
Letters.	1 1 1 2	R R R W	3	R R R G				
Numerals.	2 1 1 1	W R R R	8	G R R R				
Interval.	2 1 1 2	W W R W	Interval	G G R G		Blast.		

DISCUSSION.

Lieutenant R. T. MULLIGAN, U. S. Navy.—It is not my intention to enter into any criticism of Lieutenant Niblack's very comprehensive article on Naval Signaling, or to discuss the merits or demerits of the various *systems* and *codes* used by other nations, which he has so fully described. I shall confine myself to the *systems* and *codes* now authorized by the Navy Department for use in the United States Navy, and, if possible, offer certain suggestions as to changes or modifications in them.

I fully endorse Lieutenant Niblack in all he has said in condemnation of the American Morse Code for naval signaling, and concur with him in believing that the naval service almost demands an immediate return to the old Myer Code, modified in the direction of simplicity.

The disadvantages of the present "Army and Navy Code for Visual and Telegraphic Signaling" can only be fully appreciated by those who have had practical experience in its application to fog-signals. The only instructions, authorized by the Department, for a system of fog-signals will be found upon pages 13 to 15, inclusive, of the General Signal Book, and experience has long since proved that these instructions, even when applied to the old and almost perfect Myer Code, have failed and have fallen into disuse, being impracticable and cumbersome. Following the instructions on page 15, General Signal Book, it would take an expert signalman 6 minutes and 15 seconds to signal, "Course S. W."

In consequence of this, signal officers have, from time to time, been called upon to improvise a system of fog-signals which depended upon the *ear* and not the *watch* for its successful operation. A *time* element is dangerous and should be avoided in *any* system. As it is impossible to use the American Morse Code without the introduction of a *time* element, this is a sufficiently good reason for its being abandoned. When you attempt to apply it to the fog-whistle confusion becomes worse confounded. The *fourth* element of this code has two meanings: it may either represent a *space* or a *front*.

The advantage of the Myer Code is its extreme simplicity; it is a code of but *three* elements, and is constructed upon sound and simple principles. The *time* element is eliminated. It can be applied to the wig-wag (flag or torch), heliograph or flash lantern, fog-horn, steam whistle, bell, gun-fires, Very's Night Signals, or the "Ardois Alphabet," and to all with equal facility and certainty. The present "Ardois Alphabet" is cumbersome, and it is an *additional code* to be learned, there being no connection between the displays and the *dot* and *dash* of the American Morse Code.

The system of numerals proposed for the Myer Code is excellent; it fits in with a modified Very's Code.

My idea of flag signals is that no tactical or general signal should consist of more than three flags. By making use of the *zero* and three *repeaters* in the numeral code we have 13 one-flag signals, 156 two-flag signals, and 1716 three-flag signals, making in all a total of 1885 displays or permutations.

I am of the belief that the present tactical and general signal books can be reduced to this number of signals. It requires but a glance at any page in the General Signal Book to see what a large percentage of these signals can be stricken out without reducing its efficiency. These signals should be arranged and grouped so that those of urgency and importance would contain the least number of flags or shapes, and should be bound in one small book. The Telegraphic Dictionary and the Geographical List can be expanded to any extent; they should be as full and complete as possible, and should be bound in a separate volume. These signals need never go beyond a four-flag hoist.

I do not believe in a *flag* alphabet. By increasing the number of flags or shapes (elements) you increase the chance of making an error in each signal. Our present code (proper) consists of thirteen (13) elements, and I am firmly of the belief that with it we can make all the signals that will be necessary for the handling of a fleet and its dependencies in time of war.

If we give up this code and adopt one having 26 elements (a flag for each letter of the alphabet), we will have, in accordance with the theory of chances, in every one-flag hoist twice as great a chance of error, in every two-flag hoist *four times* as great a chance of error, in every three-flag hoist *nine times* as great a chance of error, and in every four-flag hoist *twenty-one times* as great a chance of error.

The navy needs a simple code that can be easily learned, and one in which the chance of personal error is reduced to a minimum. The proposed *flag* alphabet does not fulfill these requirements. Let us simplify the present system and not complicate it.

Very's system for *distant* signaling is excellent. The code adopted by the Navy Department is a bad one. It can at once be improved by representing the numerals by groups of four (4) stars, elimination of all brackets, and the introduction of an *interval* or *space* to separate words in a telegraphic message, etc.

If the stars were loaded in metallic shells and fired from a short double-barrelled breach-loading shot-gun, a great deal of time could be saved. The one great objection to Very's system is that it is slow.

In conclusion, I will simply state that I am of the belief that a modified Myer Code, which can be applied to the wig-wag, a modified Ardois Alphabet, a modified Very's Code, and fog-signals, would give satisfaction to the entire service.

Lieutenant H. P. Huse, U. S. Navy.—I have been very much interested in Lieutenant Niblack's excellent paper on signaling, and what remarks I have to make on it are supplementary rather than critical, and are confined to visual signaling.

Two systems of visual signals are necessary for the service, a day system and a night system; and two codes are necessary, a long-distance code and a short-distance code. This gives us four classes of visual signals; but the matter can be simplified if we use the same code for day and night short-distance work, and a second code for day and night long-distance work.

If we consider apart all signals which can be projected to a great altitude, like rockets and Very's signals, it is not difficult to reduce the question to this form, and then, I think, that most officers who have had much practical experience in signaling on board ships at sea will agree with me that the short-distance code should be based on what Lieutenant Niblack calls transient signals, while the long-distance code would better come under the head of permanent signals. If this is admitted the problem is simplified.

Short-distance Signaling by Day.—The objections raised by Lieutenant Niblack against the wig-wag are only too familiar to us. Whoever has had to send a message to several ships, no two of which could read the same signal, has felt the want of an all-around system. In fact, the short-comings of the wig-wag are so great that the flag and the torch will, it is hoped, soon be relegated to the class of only possible accessories in ship-signaling.

In 1889 Lieutenant Benson suggested to me the use of collapsing shapes, and experiments were carried on in the N. A. Squadron, first on board the Baltimore, and afterwards on board the Philadelphia, with a view to discovering the possibilities of such a system. A cone and a cylinder, each about two feet high and made with barrel hoops and bunting, were the primitive means at my command. The shapes were exposed and collapsed by means of endless signal lines and small blocks, so rigged that when the shapes were triced up aloft, a downward motion on the lines exposed the shape, and an upward motion collapsed it. The signal was sent by one man, who worked one shape with each hand. The rapidity of work was about equal to what could be done with the small wig-wag flag. The signalman had complete control of the situation, and could make a signal visible all around the horizon. Signals made to the Petrel, about half a mile off, were read without difficulty by apprentices, who had had no practice except with flags. It is to be observed that with two collapsing shapes five elements can be conveniently used. The result of the work was to satisfy me that with carefully constructed apparatus the system would prove successful. The difficulties I encountered were that the shapes were too small, and that the bunting of which they were made jammed in the blocks. Other duties and my detachment from the Philadelphia interfered with further work in this direction at the time. The code used was that embodied in Lieutenant Niblack's paper on page 471.

Short-distance Signaling by Night.—I think Lieutenant Niblack is right in his criticisms of the method used for night signaling in the N. A. Squadron in 1890 and 1891. It was found to be too slow, though very reliable. The green light is not an essential part of the system, however, and I still think that, in the event of the temporary or permanent failure of the more complex arrangements of lights required in such systems as the Ardois, the ship whose signaling outfit was thus disabled might find this simple system a great convenience. A fully equipped key-board costs only $30; the lights are the ordinary electric deck lanterns furnished. The system was first suggested to me by Lieutenant Benson.

Long-distance Signaling by Day.—I agree entirely with Lieutenant Niblack in nearly all that he says about the use of flags for signaling, but I think his suggestion, that we follow the example of Italy and adopt the international code flags, is open to criticism. In a complete system of signals, submitted to the department by Admiral Gherardi and briefly referred to by Lieutenant Niblack, a whole system of flags was designed on the followlng principles:

1. The colors best adapted for the purpose are blue, red and yellow.

2. The design of the flag and not the colors should distinguish the flag, *i. e.*, the colors should serve only to mark the design.

3. Consonants should replace numbers. It was found necessary in the development of the system to introduce one additional flag (A) as answering and affirmative pennant.

4. There should be no top and bottom to a signal flag. That is, the flag should be symmetrical in construction and design with respect to a line perpendicular to and at the middle point of the hoist.

The object of not having the color a distinguishing feature of the flag was not that signals might be read by the color-blind, but because there are conditions of light and distance when it becomes impossible to distinguish between even red and blue, and both appear simply dark, although the line of demarcation between two colors can clearly be seen. Thus at sea at midday I have seen a signal in which it was absolutely impossible with the best glass in the ship to tell whether a certain flag in the hoist was five or six. Finally the signal quartermaster was positive that it was five; it proved afterwards to have been six. The ship was the Galena, and I was the signal officer.

Anyone who has tried to do fast signaling knows the annoyance of getting hold of the downhaul of a big signal flag when he wants the hoist to hook on. It is essential to quick work that there should be no difference between the two; the top should be the end the signalman gets hold of first. Both ends should, of course, be clearly tagged.

The advantages of a system of flags designed on these principles should outweigh any small advantage to be derived from adopting the international code flags. It would, of course, be convenient to have only signal flags belonging to one code for all purposes, but the difficulty of making out some of the I. C. flags at a long distance, and the danger of confusing such letters as P and W, when the flag is not blown out clear, should of themselves be sufficient to condemn them.

The size of signal flags now issued to ships for general signaling is too large for ordinary squadron work and too small for distances above three to five miles. Two sizes might better be used, the smaller size for squadron evolutions, etc., when speed is sometimes of great importance; the larger for long-distance work, as communicating with outlying vessels on scouting duty. In this connection I may say that the very important question of sufficient altitude of masts and signal yards to admit of sufficient hoist for signals seems to have been overlooked in the design of some of our new ships. In the Baltimore this had to be remedied as soon as she

became a flagship. On none of the new ships that I have seen is there any evidence that in sparring and rigging them the question of signaling facilities has been considered as a matter of primary importance, not a *peace* importance either, but a *war* importance.

Lieutenant Niblack has so completely covered the subject of long-distance night signaling that there would appear to be little left unsaid. I can only add that the Very system, using the four-star code, always worked satisfactorily in the N. A. Squadron in 1888–1889, provided the pistols were not worn out, the cardboard cartridge cases not too much swollen to enter the chamber, or the stars not so defective that occasionally one failed to ignite at all, or did so a few feet above the water, leaving the sender in doubt whether he should fire it over or not. But with a simpler pistol on something like the old Remington model, with metallic cartridge cases, and with careful laboratory work, the Very system, with the four-star code, leaves little to be desired in the branch of long-distance signaling for which it is best adapted.

The subject of a code and the much broader subject of the general arrangement of the signal book are very tempting, and I should like to discuss them in this paper, but as an appendage to another paper it is already long enough. I must, however, call attention to the fact that much greater speed than is given by the Myer code can be obtained by using five elements instead of three, and that five elements are at our command with two lights of different colors or with collapsing shapes. A return to the Myer code would, in my opinion, be a wrong step, as it is distinctively slower than the American Morse now in use. The American Morse has never, to my knowledge, given trouble which has not been due to the inherent defects of the wig-wag system.

Lieutenant W. F. FULLAM, U. S. Navy.—Lieutenant Niblack treats the signal question so exhaustively and so practically, that little remains to be said except to comment upon the facts that are cited and the conclusions arrived at in his paper. It is conclusively proven, in this searching examination of the subject, that, in passing from the Myer to the Continental and then to the American Morse code of wig-wag signals, the navy has progressed steadily backwards during the past six years. That the army had good reasons for making these changes may be admitted, but that the navy, in following the army, grasped the shadow and lost the substance of this important matter, is clearly demonstrated.

There is, perhaps, a certain advantage in having the same code of signals in the navy as in the army, but this principle is greatly outweighed by several others, each of which is of far greater importance. The result is, therefore, that we have followed a theory based upon a single, and not very important principle, and in so doing we have neglected many practical considerations, and violated the true and vital principles that should govern the selection of a code for the use of the navy. Lieutenant Niblack has shown, beyond question, that the conditions and requirements afloat and ashore are so different that the navy should develop or select a system of

signals that are suited to its own peculiar uses. In other words, the navy cannot rely upon the army to think for it in this matter, nor can it successfully bully Nature's laws and ignore service conditions by pursuing a course that rests upon one lone idea—that of having the same code as the army.

The fatal defects of the American Morse code, and the fact that it cannot well be adapted to naval conditions, are made glaringly apparent in this paper. That the space or time element is a serious objection will be admitted by those who are called upon to read signals by this code. It is far easier to read signals by the Myer code, and surely we should have the code that renders the reading of signals as easy as possible. The difficulty of using the American Morse code with the steam whistle, the fact that it cannot be adapted to a system of night signals like the Ardois, and that a hoist of six lanterns would be necessary "to transmit the numeral *six*," are reasons enough to show that this code is totally unfit for the navy.

It is almost amusing to note the predicament in which the navy finds itself as a result of the adoption of the American Morse code. Lieut. Niblack states that "the American Morse code *cannot be used in the Ardois*, and in our service we have a *special code* called the 'Ardois' to use with the apparatus." In order, therefore, to communicate effectively with the army *at night*, the latter *must learn the Ardois code!* In other words, by adopting the American Morse, we have not even facilitated nor simplified the means of communication between the Army and the navy. *Both the army and the navy must now learn two codes!* The attempt to make one code answer is a failure—this one lone, shadowy principle, with which we have flirted, has jilted us.

On the other hand, had the navy adopted a simple and practical system *—one that could be adapted to all purposes of naval signaling, by day or night*—the army would have been put to no more inconvenience than at present, and the navy would have gained immensely *in having but one code to learn in making its own signals.* In fact, the army might also have gained, because the system that would be adapted to naval purposes would probably be simpler and more easily learned than the Ardois code.

It is hardly proper for one who has had no practical experience with the Ardois system to attempt to discuss its merits or defects. But it would appear, from Lieut. Niblack's paper, that the Ardois alphabet is by no means a good one, and that there are many serious objections to a system that requires five lights in a hoist when it would be possible to get along with four. When we consider the restrictions as to height of masts that are imposed on board small ships, monitors and torpedo-boats, it is clear that the fewer the lights the better.

Lieut. Niblack's treatment of the subject of speed and other signals used at night in squadron cruising, is very much to the point. If squadrons must manœuvre with few or no lights in time of war, officers should be prepared for such an emergency in time of peace. An officer who has always been accustomed to cruising in a squadron loaded with lights, like a torch-light procession, will experience a violent change passing into the

conditions that obtain in time of war. An officer-of-the-deck who must direct the helm, control the engine, watch the other ships, and at the same time see that three or four men hoist or lower as many lights or signals, may avoid disaster in an emergency, but it will be more by good luck than good management.

"The simpler the whole question of signaling can be made, and the fewer the codes which men have to learn, the better we will get along, as we have no corps of trained signalmen, and we require practically all our officers and men of the active combatant force to be up on signaling." This sentence sums up the whole matter, and Lieut. Niblack's plan of a modified Myer code, that can be "*adapted to all purposes of signaling*," is the true and only practical solution that has yet been proposed.

With "three service codes" and "three experimental codes in use in the North Atlantic squadron," with no official method of using the American Morse code on the fog-whistle, with no method of distant day signaling, and with a general signal book that is twenty years behind the times, it would indeed be difficult to imagine a condition of greater confusion and inefficiency than now exists in the United States Navy in the matter of signals. Under such circumstances, with important questions unsolved, with a multiplicity of codes, and poor codes at that, it is not surprising that many officers and men find themselves in in a state of complete bewilderment as regards signals. It is probable that there are now fewer officers and men who are competent to make and read signals than ever before in the history of the navy. Certain it is that the subject has never presented to them so many difficulties as at present. It may well be asked whether the navy can be considered in a state of readiness for war, with the signal question in its present condition? If this question can be answered in the affirmative, it follows that signals are of very little importance in the navy and have very little to do with the proper conduct of naval movements or operations in time of war.

Lieutenant J. M. Bowyer, U. S. Navy.—I have read with much interest the able and carefully prepared article on Naval Signaling, written by Lieut. A. P. Niblack, U. S. N., and I congratulate him upon his masterly treatment of a subject that has not heretofore received the attention that it deserves.

The changes made in recent years have not all been beneficial. I refer particularly to the changes made in the wig-wag code.

Among the officers of the navy we have lost, by a process of elimination, due to changes of code, a large number of qualified signal men. When I made my first cruise, the officers of and above the grade of master, as a rule, could not read or make wig-wag signals, the reason being that the code had been changed since they learned it. My impression is that the change referred to was made in 1870, and, although only a slight one, it was sufficient to practically disqualify a large number of officers.

It is important that all line officers should be able to use the wig-wag; but since 1870 about fifteen classes, representing more than 500 officers, have been graduated from the Naval Academy qualified in the Myer code,

only to be disqualified by the adoption of the Continental Morse, and those that learned the latter were, in turn, disqualified by the adoption of the American Morse.

The numerous changes of code would not matter so much were it not that it requires much practice to become proficient in any code, particularly when one has to forget a code or codes already learned.

I believe that the Modified Myer code, as recommended by Lieut. Niblack, would prove excellent for all purposes of signaling. The American Morse, so long as the army clings to it, would have to be taught to the signalmen.

Regarding shapes, I consider them excellent on board large ships when not engaging an enemy; but in battle, presenting as they do a large target, they would become worse than useless, because the enemy's fire would inevitably derange them so that either they could not be expanded, or, being expanded, they could not be collapsed.

I therefore favor a *preventer* set of flags, made to take the place of the shapes, for use when the latter become impracticable, *i. e.*, when they become jammed in action, and in small craft where they cannot be conveniently used.

Captain J. W. PHILIP, U. S. Navy.—Lieut. Niblack's article . . . has interested me very much, and I agree with him in his conclusions. The Myer code, with the proposed modifications, seems to me the best for adoption for all of the methods of communication. The adoption of shapes instead of flags, the masthead light, and the elimination of the fifth light in the Ardois system, are also in the line of improvement. I have asked the Department that there be placed on the fore and main trucks of the cruiser New York a double lantern, similar to that used in the Ardois apparatus, the lamps to be connected by wires to a keyboard. These lanterns are useful in case the Ardois or other apparatus is masked or out of order; they can never be masked, and would be in position for use as a white or red truck-light for squadron purposes, such as guard ship, etc.

Lieutenant T. B. M. MASON, U. S. Navy.—The lecturer certainly deserves our thanks for the intelligent way in which he has handled his important subject, and for the fearless way in which he has pointed out the defects in our present methods of communication.

He is undoubtedly correct in advocating the adoption of a four-element Myer code. The old code is the best that we have ever had, and the proposed elimination of the fifth element is a vast improvement.

The Myer code is equally adapted to the best methods of sending day and night signals now known, either visual or phonetic. That it does not correspond with the codes used in ordinary telegraphy seems an advantage, as it could be used by signalmen without being intelligible to civilian operators. A written message in the code characters could be sent or taken down in writing, on receipt, by any ordinary operator.

It would be a great improvement to use the same code with all our instruments for communicating, thus doing away with the necessity of

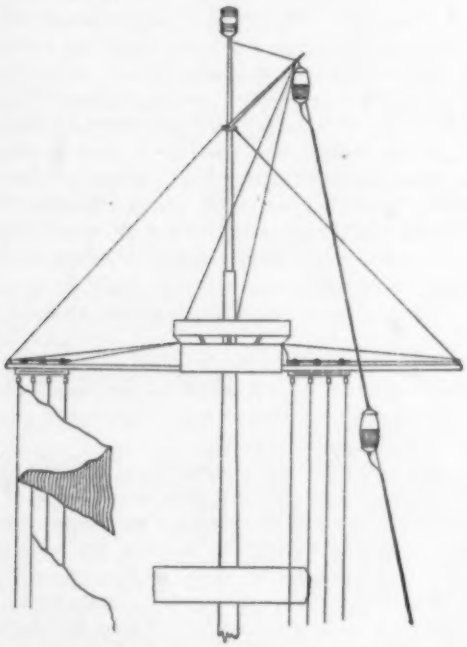
teaching our signalmen half a dozen different codes. When we had the old Myer code we had plenty of good signalmen; now we have but few, and even those are not proficient in all of the codes and often become confused.

That a distant all-around signal should be made from the highest point of the station is undoubtedly true, and an arrangement of masthead lights and shape signals absolutely necessary.

I quite agree with the lecturer in his conclusions as to what we need, and sincerely hope to see the whole subject placed in the hands of some officer of modern experience who can evolve system out of chaos and pull down our present tower of Babel.

The findings of the Philip Board will certainly be approved by every officer who has had charge of a modern ship sailing in squadron.

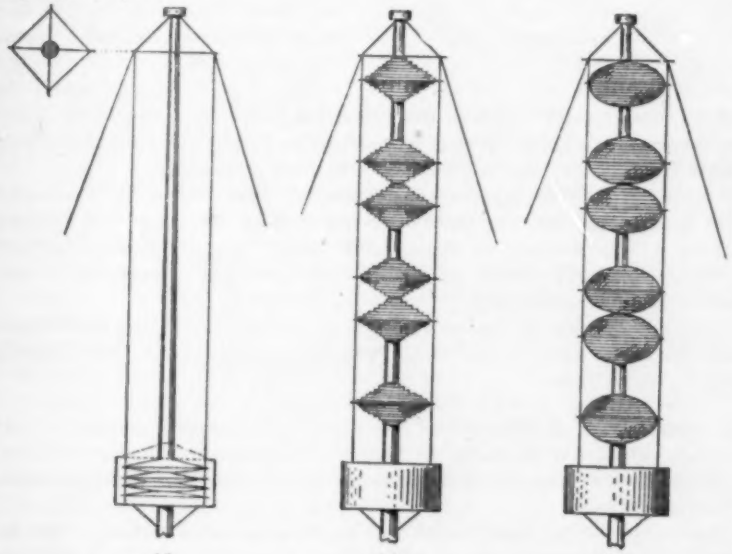
The subject of carrier pigeons is one of vast importance to us, and the service owes its thanks to those who, almost entirely unaided by the government, have succeeded in making a beginning in establishing such means of long distance communication. A single bird, reaching land from an outlying picket vessel might give timely warning of an approaching enemy, allow of a concentration and save a city.



The New York is to be fitted for masthead signaling and could easily be fitted to display the shape signals. , The above sketch shows her present signal equipment.

Lieutenant W. IRVING CHAMBERS, U. S. Navy.—I have given this subject considerable thought and agree with the writer on all the essential points. I have also conversed with many officers who have had recent experience with the confusing system of signals in present use and, without exception, the opinions expressed have favored a return to the Myer code. Give us that code, and the details of using it under all circumstances will readily follow.

I venture to disagree, however, on a minor point, where (p. 448), in a spirit of fairness, the writer wishes to point out "one rather serious defect in the Myer." Having had an exceptional amount of experience in signaling with the Myer code by fog-whistle (on board the steamship Loch Garry, with the Greely Relief Fleet, where I had personally to attend to all the signaling, very much of which was in fog or thickly falling snow), I can stoutly affirm that no such defect exists, if we regard 1 as a *blast* (of any duration) and 2 or 3 as two and three *toots* respectively. In this case Y is simply 3 blasts, and "front" (or interval) 3 toots; N is 2 blasts, and T is 2 toots. It is very easy to make this distinction between a group of toots and a blast, and my experience teaches me that if the sounds, toots or blasts, are of equal duration, the result, especially with a "*smart* signalman" who is trying to show off, is a confusing succession of sounds improperly spaced.

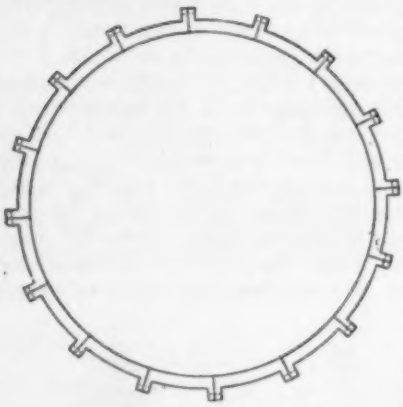


(*d*). (*a*). (*b*).

In regard to the proposed arrangement of shapes for distant day visual signaling, I think practice would demonstrate that the varying effects of atmosphere and light would frequently so distort them as to render it difficult to distinguish the difference between the two, and that the

mechanical difficulties of the arrangement of two shapes in one would prove too great for smooth working. I would, therefore, suggest that the shapes be *all alike* and *double*. Figures (*a*) or (*b*).

For all collapsible shapes I would prefer some such preparation as oiled silk to rubber, on the score of durability, and should wish to arrange the covering so as to prevent access of water to the springs and joints. The difficulty of mast construction would enter as a factor. We would need light masts with about sixteen grooves, and this difficulty could perhaps be met by making the small masts as shown in figure (*c*). The flanges should be flush riveted.



(*c*).

This, to my mind, is the best method of construction for *all* military masts; but that is somewhat outside of this subject.

I fancy, however, that the simplest and best (though perhaps the slowest working) arrangement of signal shapes would be that whereby the shapes were *wholly hoisted* at each display, and such device might be tried on any mast of sufficient height. Figures (*a*), (*b*) and (*d*).

The double shapes would require a little greater length of mast than the single shapes, and the hoisting shapes a little greater length than fixed shapes, but a mast 50 feet in clear would amply suffice for double shapes of 4 feet diameter.

I do not think that torpedo-boats or torpedo hunters should be provided with Ardois lanterns, but should be required to rely upon the flashing masthead lantern which all ships should have. The most important war or lookout warning signals should be arranged to be transmitted by one lantern in the shortest time.

I think the thanks of the service are due to Lieut. Niblack for the zeal and patience he has displayed in following up this subject, which is of rapidly growing importance.

Commander C. M. CHESTER, U. S. Navy.—It is only necessary for one to have attempted to study the subject of signals in the navy to comprehend the vast amount of labor that has produced the excellent paper of Lieut. Niblack.

Assuming that we are to retain our woefully complex system, which has resulted in the common practice of making a signal to "send a boat," and then returning the message by a bearer of dispatches, the propositions of the lecturer become valuable. Indeed the paper is full of valuable suggestions for any system of signals, but what I would impress upon the Association is that our present code of signals is entirely inadequate to the growing demands of the service.

The U. S. Navy Code of Signals consists of 10 elements, represented by 10 digits, which, combined in groups of 4, allow 9999 signals to be indicated. As our signal book contains many more than this, we resort to repetition of numbers, qualified by a pennant or signal to go before. Should the pennant be obscured, as it frequently is, a signal sent to "Ram the enemy at full speed" may be interpreted "How," or the reverse. In order to make all the possible combinations of the signal code, we use at the present time 31 flags. This cumbersome system has resulted, as I have said, in sending messages by boats, rather than as signals, and thus preventing the practice in signaling which is an absolute necessity for preparation for battle.

In 1889 Commander C. H. Davis proposed an entire new departure in signals, based upon the system of the International Code. His communication was referred by the Department to the Board on Organization, and, after a careful investigation, its adoption was recommended.

The system contemplated the use of 20 elements, represented by 20 consonants of the alphabet. It is only necessary to work out the permutations possible, to show that over 116,000 signals can be made with four flags, or other symbols; ample to accommodate any code, without repetitions.

The great advantage claimed for the system is that no combination of flags can have a double meaning.

Having been detailed by the Bureau to prepare a new code of signals, on the basis of the recommendation of the Board of Organization, I worked continuously on the subject for over a year, and submitted to the Department what was to be known as the "Introduction to the Code" and the "Fleet Evolutions," and left the "General Signal Book," partially completed, in the hands of Lieut. John F. Parker, in April, 1891.

As the most difficult part of signaling takes place during the night, and as at this time communication is generally more necessary, the code was prepared to cover these requirements, knowing that day signals would easily be assimilated to the night code.

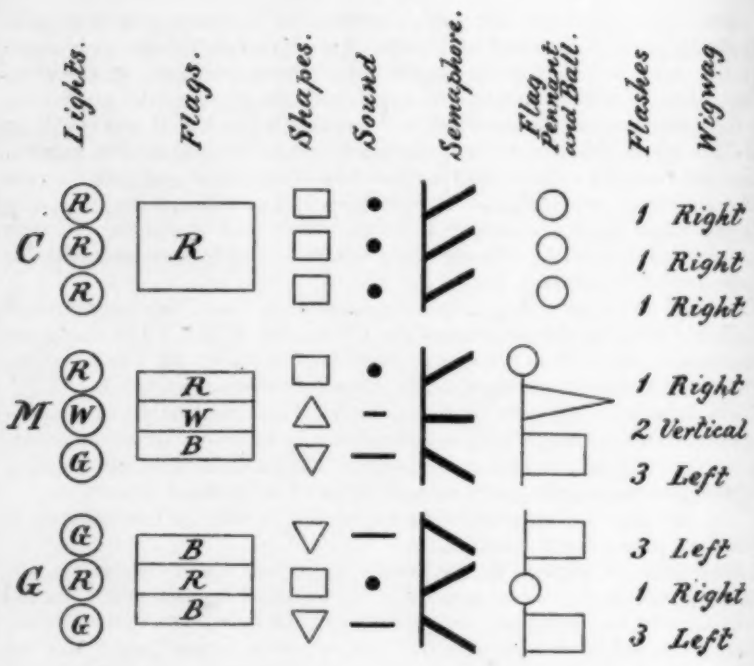
In the proposed code the object has been to combine the fewest number of elements that will contain all the symbols used, without *repetition*, for in repetition there is danger.

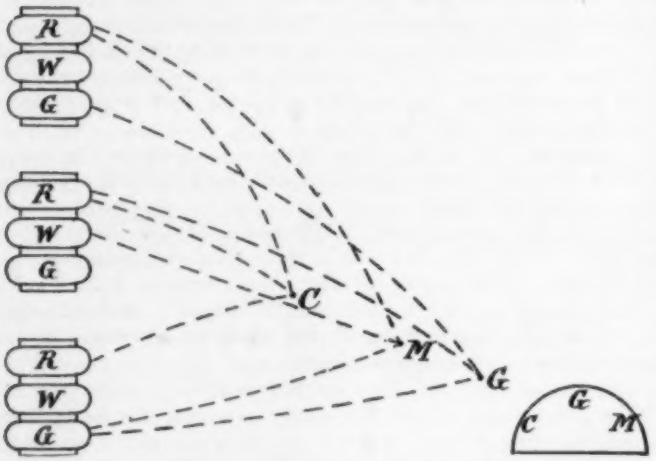
It is apparent that two elements, which make only nine combinations in permutation, cannot be used; but that three elements, permitting twenty seven combinations, will suffice for all the requirements of the service.

It is made mandatory that all signaling in the navy should be done by the Navy Code, thus insuring the facility in its use necessary in war by constant practice with it in time of peace.

The following sketch will illustrate the method of using the various symbols in combination, and it is readily seen that any three dissimilar objects may be utilized.

It is hardly necessary to go into a description of the code, but by permutation the three elements, called, say, red, white and green, represented in any way desirable, enable us to make the twenty seven letters of the alphabet. Taking twenty of these for the code proper, we have six letters left for the qualifying signals, "Interrogatory" and "Preparatory" (the





only two used), and the "Answering," "Annulling," etc. The "&," or 27th letter, has a special signification, described in the "Introduction to the Code."

The "Signal Book" has three parts, besides the introduction.

The "Fleet Evolutions" contains:

1st. 20 "Battle Signals," indicated by a single flag.

2d. 380 "Evolutionary Signals," indicated by a hoist of two flags each.

The General Signals are all made with three-flag hoists, and the book has a possibility of 6840 signals; a larger number than in the present signal book.

The Telegraphic Signals are made with four-flag hoists, and there can be made 116,280 signals. Thus additions to the present Telegraphic Dictionary may be made and its scope greatly increased.

The General Signal Book contains a numeral table, similar to that in the International Code, so that any number may be expressed by the letters of the code.

There are, however, ten auxiliary symbols, used to indicate the nine digits, shown by pennants in the day signals, and by two lights at night. The "Zero" and "&" are identical.

Thus messages in numerals may be sent, without the numeral table, although, where confusion from long distance or other causes are likely, they would not be used.

The night signal method, described in the "Introduction to the Code," consists of three electric lanterns, each with a red, white and green shade, arranged vertically, with nine wires, leading to a keyboard, containing the twenty seven letters and ten numerals. The key indicating a letter closes the circuit for one color in each of the three lanterns, while that for a numeral shows two colors, in the same way. The search light is used by showing one, two or three flashes, corresponding to red, white or green of the code.

The sound signals are, dot, short dash and long dash.

The wig-wag, as right, left, vertical, corresponding respectively to the red, white and green of the code.

A very imperfect description from memory of the proposed code has been given, but I will have accomplished my object in taking part in this discussion if the necessity of discarding the old system, with the old ships of war, be shown and substituting something else for a different class of vessels. This, I think, is better than to rehabilitate the old Myer code, as suggested by Lieut. Niblack.

A prime feature of the proposed navy code is the use of shapes for distant signaling, as well as for use on board the low, mastless vessels, which are likely to be common in the future.

I worked for some time over an idea by which the three shapes, square, cone, and inverted cone, could be displayed mechanically on a hollow iron mast, from a turret, but other duties prevented my completing the project.

The semaphore symbols of the code can be easily worked this way, and even this is better than trying to hoist the 4, 5 or 6 flags necessarily used

at present. It may be said that the three colors taken as the basis of the new system are objectionable, particularly in the Very code, and yet Mr. Very himself has recommended their use, and the Italian navy has adopted his recommendations.

The changes made from the Myer code to the English Morse, and later to the American Morse code, were properly made to accord with the army, that we might communicate with that branch of the service, when necessary. In doing so we have almost lost sight of the fact that we have a navy code, upon which we must rely in war time, and which, by disuse, will have become of little value. I would keep the American or English Morse or Myer code to talk to our army friends, as we would send a telegraph message (through an operator), but it should be held as almost a misdemeanor to communicate with our sister ships in anything but the language we shall use during battle.

The drills in signaling should be as rigid as the requirements of the old spar and sail exercises.

Lieutenant H. S. KNAPP.—The paper given us by the writer is an excellent presentation of the inefficiency and insufficiency of the present means of signaling in use in the navy, together with a remedy therefor. Every officer who has been cruising recently can testify to the confusion resulting from the use of our many different codes, service and experimental. Every officer, from admiral to cadet, *ought* to be able to understand any signal that he can see, or hear; and if we had a systematic code, carefully and consistently worked out, it would not be too much to expect of any officer that he should be familiar with all sorts of signals. As it now stands, one needs the memory of a Loisette to remember all the codes with which we are burdened.

From personal experience, I can heartily endorse all that Lieut. Niblack says regarding the shortcomings of the American Morse code. Without criticising the reasons that led to its adoption, I unhesitatingly express the opinion that it has been shown painfully cumbersome and inadequate to naval needs. It is harder to learn and more difficult to retain, and it is distinctly slower than was the Continental Morse or the Myer. In doing away with it, however, I am disposed to favor a return to the Continental Morse rather than to the Myer, and for two reasons: first, an army signalman learning the navy code, or a navy signalman learning the army code, would have many less letters to learn over, owing to the duplication of sixteen letters in the two Morse codes; secondly, it would be possible with it to communicate with foreign ships using the same code. It is worth while getting as close as possible to the army in the matter of signals, though it is quite unnecessary to adopt a code for the simple reason that it is the one in use by the army; and the desirability of a common signal code in combined operations with the naval force of other nations, a not infrequent occurrence, was proved during the time that our service used the Continental Morse. Lieut. Niblack himself shows that the Continental Morse can be used in the same way as

he proposes to use the Myer. Either would have to be *modified* to make it a four-element code, and either gives thirty characters when so modified. With the universally accepted convention that the dot is indicated by a motion to the signalman's right, and a dash by the motion to his left, the rest of the general scheme works itself out as well with the Continental Morse as with the Myer.

The scheme is a valuable one as showing that a consistent code can be evolved for all purposes. I have never made any special study of flag or shape codes, and do not feel competent to criticise the changes in these regards proposed in the paper. But I venture to express the hope that, when a code shall be finally adopted, as much attention be given to the instruction of officers and men in general and night signals as is now devoted to the wig-wag. My experience goes to show that most of the instruction given afloat in signals is in the use of the wig-wag code.

That the Ardois, or some similar, apparatus has come to stay there is little doubt. Lieut. Niblack claims for it the advantages of "rapidity and accuracy in signaling." The latter point is freely granted, and the value of that sort of apparatus for night work is unquestioned for that reason if for no other. Moreover, its range is very considerable. I doubt, however, the practicability of its use on low-masted vessels, and consider the use of either the modified Continental Morse or Myer code with the two-element truck-lamp, fitted with Fresnel lenses, the best substitute for it. As a "preventer" on any ship these truck-lamps should always be fitted. I believe that, with a proper keyboard and an arrangement whereby a reduced current could be made to flow constantly through both lamps, sufficient to keep them at a low red heat while signaling, nearly or quite as great speed could be attained as with the Ardois, though not with the same certainty of the signal's correct reception, of course.

The report of the Philip Board concerning night speed-signals and Lieut. Niblack's remarks thereon appeal to every watch officer. To say that the present regulation speed-lights are a nuisance is to state the case mildly. To be of any value, they should be electric lights (during the time I was attached to the Squadron of Evolution one ship used oil lamps habitually, and as habitually the officers-of-the-deck of the other ships placed no dependence whatever upon the display); also, to be under the immediate observation and control of the officer-of-the-deck, they should hoist from or near the bridge. But in that situation, the glare resulting is a serious source of danger. A squadron is not on dress parade at night; every purpose is gained when the vessels keep in good touch—near enough for mutual support and to be well in hand by the Commander-in-chief, and far enough apart not to endanger one another. These objects can be attained without speed-lights and the lights should go. We ought to discard them in peace and so gain the experience and confidence in night squadron sailing under war conditions that would be of utmost importance in case of actual hostilities.

[NOTE.—Should any members of the Institute desire to add to the discussion of this paper, an opportunity to do so will be given in the next issue of the PROCEEDINGS, in which Lieutenant Niblack will reply to the discussion.—ED.]

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U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

CRUSHER AND CUTTER GAUGES FOR EXPLOSIVES.

By W. R. Quinan, Member U. S. Naval Institute.

The subject of explosives is one upon which we need light. Though in the last two decades we have made some progress in their study, our theories are still disjointed and incomplete. The first assured step in this progress, as indeed every subsequent step, has been gained by subjecting explosives to scientific tests and measurements. Means of measuring mass, time and space have been the three agents of progress. One of the recent contributions to this good work is a paper by Lieutenant Willoughby Walke, 2d Artillery, instructor in charge of the U. S. Artillery School Laboratory, published in the Journal of the American Chemical Society, Vol. XII, No. 7, Sept. 1890. This paper, whatever may be its defects, has the merit of being perfectly impartial. Lieutenant Walke has no particular explosive to exploit. It is to be hoped that he will continue his investigations. In making his experiments he "decided to use the Quinan pressure gauge, both on account of the degree of accuracy with which it registers the pressure, and because of the ease with which the apparatus is manipulated."

In the description which originally presented this instrument to the public, no originality was claimed for it. The apparatus in other forms had been used by other experimenters. So far as I know, the first description of such an instrument used for testing high explosives was published by the late Henry S. Drinker (see "Tunneling, Explosive Compounds and Rock Drills," page 77); so if there is any credit due, it should go to him. Especially so, since with this instrument he demonstrated beyond a doubt the cardinal principle of modern dynamites, viz., that an explosive dope adds materially

to the force of nitro-glycerin, a fact which had been disputed by Mowbray and received no countenance from Hill, Trauzl or André (see pages 71 and 72).

Out of deference to Drinker, my apparatus was called also a "pressure gauge." The better term, "crusher gauge," will hereafter be used.

The Drinker gauge can be succinctly described in his own language as follows, omitting the references to the drawing: "A third apparatus was tried, which we will term a pressure gauge. It consisted, as shown in the figure, of a vertical steel pin 6¾ inches long, 1½ inches in diameter, enlarged at the top to 4 inches. This pin weighed 8½ pounds, and it slid vertically (through a hole) in an iron block, which block was bolted to an iron foundation weighing some 1200 pounds. The pin rested upon a small truncated cone of lead which itself rested upon the foundation." We will add that the block was recessed under the pin so that the lead plug could be manipulated; also that the top of the pin (or piston) was flat, and the *shot* had a recess or cavity to make room for the charge.

The objection to Drinker's gauge for regular work is that the piston is too light, and gets jammed by upsetting. There is also some risk, as the explosive is not confined by a cavity in the piston, but is liable to get scattered on the flat surface. Liquids cannot be tested at all.

The following description of the Quinan gauge is republished, so that the discussion which follows may be intelligible to the general reader.

Pressure Gauge.

"Guided by this reasoning I was lead to adopt, as my test for the higher grades, the instrument misnamed the 'Pressure Gauge,' in which the force of the powder is measured (indirectly) by the compression of a plug of lead. I do not pretend to any originality in this apparatus, as similar instruments have already been used for this purpose. (See Drinker on *Tunneling*, page 77.) The particular form, however, devised by me, having been tried by many hundred experiments, and having proved satisfactory in every respect, merits, I think, a detailed description.

As shown in the drawing (Fig. 1), it consists of a heavy block of wood, upon which is bolted a cast iron block or base. In this base are inserted four wrought iron guides, or standards, set around

the circumference of a four-inch circle. The lead plug rests upon a steel disc (not apparent in the drawing), which is let into the iron block flush with its upper surface. A ring holds the guides in place at the top, their ends being reduced to screw-bolts, passing through the ring, which is held down by nuts.

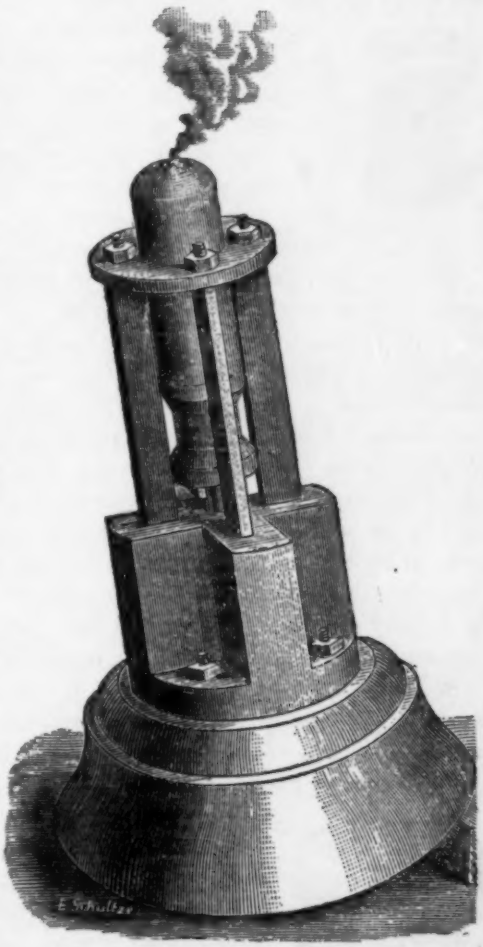


FIG. 1.—Pressure Gauge.

The piston (Fig. 2), which is the piece resting on the plug of lead, is a cylinder of tempered steel, four inches in diameter and five inches in length. It is turned away at the sides to lighten it as much as possible. It moves freely between the guides. In the top is a parabolic-shaped cavity to hold the charge of powder. The weight of the piston is twelve and one-quarter pounds.

The shot (Fig. 3), made of tempered steel, is four inches in diameter and 10 inches in length, weighing thirty-four and a half pounds. It is bored through its axis to receive a capped fuse.

To operate the instrument, a plug of lead is placed upon the steel plate within the guides. The piston is put down gently upon it, and the charge of powder placed in the cavity. The shot is next lowered gently upon the piston, and the capped fuse pushed down through the hole in the shot. The fuse being lighted, when

the fire reaches the cap the charge is exploded, throwing out the shot and compressing the lead plug. The accuracy of the test is based upon the assumption that the lead plugs shall be of uniform density and homogeneous structure. The form of plug adopted was a cylinder, one inch in diameter, and one inch in length (Fig. 4).

FIG. 2.—Piston of Pressure Gauge.

In regard to the kind of plug, my choice lay between plugs cast in molds, and plugs cut from a solid bar, which could be obtained of the desired dimensions in the factories.

This lead bar, though not made of perfectly pure lead, is manufactured from large masses of metal, is very dense, and can be obtained in lengths of 50 feet. It seemed to me that the desired uniformity would be more likely to obtain in this product than in plugs cast, one at a time, from small masses of metal. Having prepared plugs of both kinds, the next point was to test their relative merits for my purpose. The nature of this test was fixed by an additional and independent consideration. It should be borne in mind that while being compressed by the explosion in the pressure gauge, the density of the plug as well as the lead surface opposed to the piston continually increases. It is plain from this that the amount of compression shown by the plug is not a direct measure of the strength of the powder. For illustration: if one powder, exploded in the pressure gauge, compresses a plug $\frac{250}{1000}$ of an inch, and another powder compresses a plug $\frac{500}{1000}$ of an inch, the latter powder would be twice as strong as the former if the compressions were direct measures of relative strengths. But in fact the latter powder is more than twice as strong. The problem was, how much. As a practical measure of the strength, I assumed it proportional to the *work* performed in reducing the height of the lead plug. To get an expression for the work, it was only necessary to find the number of foot-pounds required to produce the different amounts of compression. Acting upon this reasoning, an apparatus was built as shown in Fig. 5.

FIG. 3.—Shot of Pressure Gauge.

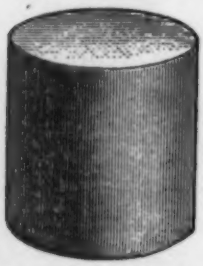


FIG. 4.—Form of Lead Plug used in Pressure Gauge, Full Size.

It consisted of three boards, so connected as to form a slide sixteen feet high, in which a weight (the shot of the pressure gauge) could fall freely. One of the boards was graduated into feet and half feet. The horizontal board at the bottom, upon which the others were nailed, rested on a heavy post set deep in the ground. A round tenon formed on the top of the post projected through a hole in the board. On the top of this tenon, turned bottom upwards, was placed the piston of the pressure gauge. This served as the anvil, and on it the plugs were placed. The fuse-hole of the shot was plugged with a large wire, which projected through the top and gave a hold for a simple form of clutch, by means of which and a light rope passing over a pulley at the top of the structure, the shot was hoisted to any desired height. The clutch was released by hand from the steps of a ladder.

FIG. 5.—Foot-pounds Machine

My first work with this apparatus was to test the uniformity of both kinds of plugs. In selecting the cast plugs for test, they were carefully weighed, and all above or below a certain standard, as well as those showing any signs of flaws or other defects, were rejected. The first half-dozen blows upon the cast plugs showed such anomalous results that I rejected the whole batch, and molded a new lot, hoping by varying the method to obtain more homogeneous castings. The experiments with these, however, were far from satisfactory.

Turning next to drawn plugs, I had the satisfaction of finding them remarkably uniform. The plugs were carefully measured before compression and again after compression, by taking the average of several measurements. The difference between the original length and the reduced length gave the compression caused by the blow of the shot in falling.

The instrument used in measuring the plugs is the micrometer calipers, manufactured by Brown & Sharp (shown in the drawing Fig. 6).

FIG. 6.—Micrometer Calipers for measuring Lead Plugs.

It is exceedingly accurate and convenient, and reads to the thousandth part of an inch, and even this space can be readily divided. The more uniform structure of the drawn plugs as compared with the cast is apparent in the different appearances of the two after reduction in the pressure gauge or in the foot-pounds machine. The drawings (Figs. 7 and 8) show this better than description. Having adopted the drawn plugs, I proceeded to construct a table for converting the compressions of the drawn plugs into foot-pounds, or actual measures of the strength of powder. This was simply and expeditiously done by making several series of experiments in dropping the shot from various heights, beginning with a half foot and going up a half a foot at a time to about sixteen feet. An average of all the compressions at a given height was assumed as correct. The height multiplied by the weight of the shot gave the foot-pounds corresponding to that particular compression.

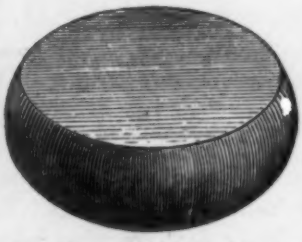


FIG. 7.—Drawn Lead Plug after compression.

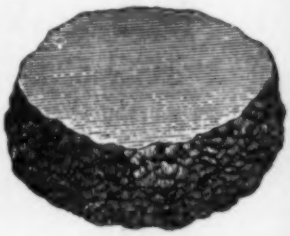


FIG. 8.—Cast Lead Plug after compression.

To more graphically represent the relations between the plug compressions and foot-pounds, as well as for convenience in my work, I constructed a diagram, using the compressions as the ordinates, and the foot-pounds as the abscissas of a curve.

The extreme co-ordinates were fixed by nitro-glycerin.

This diagram, 21 x 14 inches, has been relied upon for converting plug compressions into foot-pounds, or units of strength. My standard charge for the pressure gauge is 24 grains."

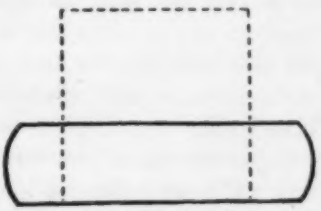


FIG. 9.—Section of Plug showing reduction in Pressure Gauge.

The diagram referred to, together with the original record of the experiments with the foot-pounds apparatus, was destroyed by fire in my laboratory several years ago. However, the curve will be found very accurately reproduced in the dotted line on Plate I.

When Lieutenant Walke was preparing for his experiments he wrote to me for a copy of the diagram or table from which it could be constructed. At that particular time I could not furnish the required data. Since then I have got possession of my note books in which I had recorded several hundred plug compressions by different explosives (covering the whole range of the curve) with the corresponding foot-pounds taken from the diagram. These have enabled me to replot the curve very accurately. Of course there were some mistakes among these co-ordinates, but the error was generally so large as to leave no doubt about the propriety of rejecting it in constructing the curve.

In using the crusher gauge for testing high explosives I have assumed that a given compression of a lead plug denotes exactly the same amount of work, whether the compression be caused by a falling weight or by an explosive—not a very violent assumption, and yet I doubt if it is strictly true. However, we are not prepared to discuss this point just now.

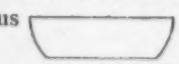
Comparing great things with small, it is a satisfaction to know that General Abbot, working independently upon the same subject, adopted the same material—lead—to record the action of his explosives, and determined the foot-pounds corresponding to plug compressions in substantially the same way. He used the blow of a swinging pendulum for this purpose. For his unit, however, he adopted *intensity of action*, which he defines as the mean pressure, to obtain which he divides the foot-pounds representing the kinetic energy or work of the pendulum hammer by the path described by

the point of application of the force in its line of direction ; that is, he divides the work expressed in foot-pounds by the plug compressions expressed in feet to obtain the mean pressure in pounds. He used lead plugs of different sizes, which gave different paths for the same work, and, consequently, different mean pressures for the same force. To overcome this difficulty, he decided to translate his energies into mean pressures by adopting the indentation of Rodman's pointed indenting tool into discs of copper as the uniform path to be used (see page 26 of his "Report on Submarine Mines").

General Abbot's problem was much more difficult and intricate, in that the blows of his explosives were transmitted through water, and the law of variation in energy and intensity with weight of the charge, depth of submergence, distance and angle of direction, had to be determined, while a host of minor conditions had to be dealt with and disposed of.

His methods, in my opinion, are beyond criticism. Thoroughness in practical experimentation is supplemented by equal thoroughness in analysis. No labor is shirked, no guessing is indulged in, no short cuts taken to doubtful conclusions. The task imposed was herculean ; its accomplishment has a singular completeness and definition. The Report is a model of careful and accurate work in a new field.

Laws of Compression of Cylindrical Lead Plugs.

We return to a consideration of the curve on Plate I (see broken line), which gives the relation between plug compression and the corresponding work in foot-pounds for a certain kind of cylindrical one-inch lead plugs. This curve was constructed from experiments with the foot-pounds or falling weight machine. The plugs compressed in this way were remarkably uniform in appearance. Figure 7 (page 512) gives a good general idea of their shape. Now, in examining a variety of plugs *compressed by explosives*, I have made certain general observations, as follows: For moderate compressions the plug remains a true cylinder; this form holds good up to a compression of about .200". For higher compressions, say up to .400", the plug departs more and more from this form and becomes barrel-shaped. At still higher compressions it becomes tub-shaped —large end up—sides slightly rounded, thus  ; at .600" this form is quite marked.

The retention of the cylindrical form for even moderate compres-

sions is rather remarkable, and shows that the flow of the metal is equal in all the horizontal layers.*

It occurred to me that the change of form might be due to or, at least, accompanied by a corresponding change of density, and that the density for small compressions might be sensibly uniform. I therefore weighed in air and water five plugs. One was of original full length as cut from the bar, the others had been subjected to various degrees of compression up to .670″. The first was a true cylinder, one inch in diameter, the next was a cylinder of greater diameter, the next two were barrel-shaped, and the last was a flat disc 1¾ inches in diameter across the top, with a decided tub shape.

The original lengths varied from .983″ to .992″. The results were as follows:

		Wt. in air. Grammes.	Wt. in water. Grammes.	Sp. gravity.
1.	Original plug,	144.45	131.76	11.383
2.	.159″ compression,	143.78	131.15	11.384
3.	.305″ "	144.95	132.22	11.386
4.	.409″ "	145.11	132.37	11.390
5.	.670″ "	145.09	132.37	11.406

Although the scales were not delicate enough for very fine work, a law of change in density is clearly shown, and, so far as the evidence goes, it disproves my assumption that the density remains constant for small compressions. I was led, however, by this erroneous assumption into the following speculations, part of which are certainly more curious than useful, but may, nevertheless, be of interest. If we assume that the density remains the same, and that the plug retains the cylindrical form throughout (which is not very far from being true), the relation between compression and work can be readily deduced, for the resistance will then be directly as the area of the surface pressed, and the volume being constant this area will bear a simple relation to the compression.

Let y = compression.

L = original length of the plug.

$L - y = s$ = reduced length of the plug.

A = area of top of the plug.

* The same remark applies to the small copper cylinders used by ordnance experts for taking powder pressures in guns. Those that I have seen preserve the cylindrical form very accurately for moderate compressions, either by powder or by a falling weight.

V = volume—constant.
K = a constant—the resistance per unit of area.
R = variable resistance.
x = work of compression.

Then $R = A\,K$, and since $Az = V$,

$$R = \frac{KV}{z} \text{ or } Rz = KV,$$

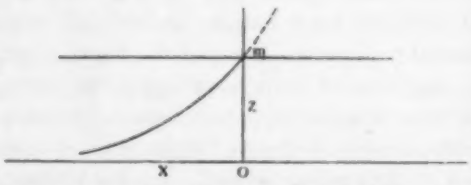
which is the equation of a hyperbola referred to its center and asymptotes.

For simplicity we assume the asymptotes to be at right angles to each other. Then since

$$x = \int R dz = \int KV \frac{dz}{z},$$

we have $x = KV \log z + C$, x being the area included between one branch of the hyperbola and the asymptotes.

If we call L—the original length of the plug—unity and make this the ordinate of the vertex from which to estimate the area, we have $Z = 1$, $KV = 1$, $C = 0$; whence $x =$ Napierian log z. That is, the work of compression is the Napierian logarithm of the reduced length of the plug when the original length and the resistance at the beginning are each considered unity. z being less than unity, x will be negative, and we consider only that part of the logarithmic curve to the left of the axis of z, or axis of numbers.



The curve, like all logarithmic curves, crosses the axis of numbers at the distance unity from the origin, and, since the modulus is unity, it crosses at an angle of 45°—the modulus being equal to the subtangent on the axis of logarithms. The axis of x is an asymptote to the curve.

To express the equation of the curve in terms of y, we transfer the origin to the point m, which gives $x =$ Napierian log $(1 - y)$.

This value for the work is expressed in terms of the length of the plug and of the primary resistance, each taken as unity, and is not directly comparable with *foot-pounds*.

To make such a comparison we must assign a modulus to the system of logarithms which is perfectly legitimate on other grounds, since we could have referred the original equation of the hyperbola $Rz = KV$ to asymptotes which were oblique to each other, in which case the sine of the angle included by them would have become the modulus of the system.

In selecting a modulus we have a small latitude. Properly we should take a modulus which would cause the logarithmic curve to make the same angle with the axis of y or z, as does the actual curve constructed from experimental data. Determining this angle would depend upon the accuracy of the construction. We can arrive at nearly the same thing by assuming the curves coincident for small values of y.

Following is a table of values of x (corresponding to the assumed values of y) deduced from the equation, $x = \log (1-y)$ and also from $x = .234 \log (1-y)$, the minus sign of x being omitted.

y = compression.	x = work.	
	$m = 1$	$m = .234$
$y = .050$	$x = .051$	$x = .012$
$y = .100$	$x = .105$	$x = .025$
$y = .200$	$x = .223$	$x = .052$
$y = .300$	$x = .356$	$x = .083$
$y = .400$	$x = .511$	$x = .120$
$y = .500$	$x = .693$	$x = .162$
$y = .600$	$x = .916$	$x = .214$
$y = .700$	$x = 1.204$	$x = .282$

In plotting the logarithmic curve corresponding to the modulus .234 for comparison with the experimental curve, since y expressed in thousandths of an inch is taken as a whole number, the values of x must be multiplied by 1000 also, or the numbers in the last column above taken as whole numbers. The curve will be found on Plate I.

For plugs of one inch diameter we see that there is no close agreement between the logarithmic curve and the actual. But the former was deduced under the assumption that the density remained the same and that the plug retained the cylindrical form, neither of which propositions is true. It will hereafter be shown that for plugs of smaller diameter the agreement of the logarithmic curve with facts is closer, but we will now try to deduce a form of equation which is

more flexible than the logarithmic and better adapted to represent the relation between work and compression. It is true we cannot apply the same rigid course of reasoning in deducing it, but the result seems to be reliable for practical use.

As to the general form of the equation: first, it must be such that the curve passes through the origin—that is, it has no absolute term; second, it must be concave towards the axis of x $\left(\frac{dy}{dx}\right.$ a decreasing function of $\left.x\right)$; third, L being the original length of the plug, a line parallel to the axis of x at distance L must be an asymptote to the curve.

The simplest equation to fulfil these conditions that has occurred to me is

$$x = \frac{y}{L - y} \text{ or } y = \frac{Lx}{1 + x};$$

in fact, it is too simple for our purpose. It is probable that y needs both a coefficient and an exponent to represent the curve. Giving y a coefficient B, we have

$$x = \frac{By}{L - y}, \text{ in which } L = 1000.$$

Testing this by applying it to the dotted curve of Plate I, we determine the value of B from some of the co-ordinates taken from the curve, as follows:

Foot-pounds.	Comp. $\frac{1}{1000}$ inch.	
$x = 30$	$y = 100$	$B = 270$
$x = 80$	$y = 200$	$B = 320$
$x = 145$	$y = 300$	$B = 338$
$x = 233$	$y = 400$	$B = 349$
$x = 356$	$y = 500$	$B = 356$
$x = 430$	$y = 550$	$B = 352$
$x = 530$	$y = 600$	$B = 353$

The only glaring anomaly in this table is $B = 356$, which, it is plain to see, results from the flattening of the curve about this point. We conclude, however, that B is not a constant, as it should be if the equation were adequate, and that y needs an exponent greater than unity. The equation then becomes

$$x = \frac{By^a}{L - y};$$

L in this particular case being 1000.

I determined a number of values of a and B by using the values of x and y, given above, taking them in sets of two. This process gave values for B ranging from 160 to 210, and corresponding values for a from 1.2 to 1.05. Each set of these, applied to the equation above, determined a curve agreeing more or less closely with the dotted one and coinciding with it in at least two points. I finally selected as the best values those in the following equation:

$$x = \frac{190y^{1.1}}{1000 - y},$$

and the full curve in the plate is constructed from this.

The following short table of co-ordinates gives a comparison of the values of x as taken from the dotted curve (or rather from one drawn previously on a larger scale), and the values of x calculated to the nearest whole number from the above equation:

Compression in $\frac{1}{1000}$ inch. y.	Foot-pounds, dotted curve. x.	Foot-pounds, computed. x.
50	12	15
100	30	33
200	80	81
300	145	144
400	233	231
500	356	354
600	530	540

By means of this table the plotting of both curves on Plate I can be checked. The plotting is not perfectly accurate. Except at the extremities the agreement of the two curves should be closer than shown by the plotting.

We can also deduce a general equation of the form

$$x = \frac{By^a}{L - y};$$

in this rather clumsy way: If in the equation

$$R = \frac{KV}{s} = \frac{KV}{L - y},$$

we assume R to be the *mean* resistance corresponding to the compression y, K and V having suitable values, we have the following simple expression for the work,

$$x = \frac{KVy}{L - y}.$$

But K and V are no longer constants. V, the volume, diminishes slightly as y increases. Its particular value in this equation corresponds to some fractional part of y. K, the resistance on the unit of area, increases as y increases, but its value also corresponds to some fractional part of y. The product KV is, therefore, a function of y, probably of the form $CKVy^b$, in which C is a constant, K and V have their *primitive values*, and b is a fractional *exponent less than unity*. Substituting this for KV in the equation above, omitting C, and placing $1 + b = a$ for a new exponent, we have

$$x = \frac{KVy^a}{L - y},$$

as our general equation for cylindrical lead plugs, in which

x = work expressed in foot-pounds,
y = compression expressed in $\frac{1}{1000}$ of an inch,
L = original length of the plug expressed in $\frac{1}{1000}$ of an inch,
V = original volume of the plug,
K = constant depending on the nature of the lead,
a = number between 1 and 2.

The only other recorded comparison of the compression of lead plugs with the work required to produce them, that I know of, is given in General Abbot's Report (page 22). His plugs were all made from a single lot of lead selected at the Rock Island Arsenal. They were made by casting and compressing in a mold, the surplus lead being allowed to escape through a small hole. Five sizes of plugs were used, $\frac{75}{1000}$, $\frac{6}{10}$, $\frac{5}{10}$, $\frac{4}{10}$ and $\frac{3}{10}$ in diameter. The first three sizes were about 1 inch long, the $\frac{4}{10}$ was .8 inch long, and the $\frac{3}{10}$ was .6 inch long. The table of the compression of these with the corresponding foot-pounds by the pendulum hammer is given on page 22 of the Report. We have constructed the curves represented in this table on Plate II. In the construction the same linear value is given to one foot-pound as to $\frac{1}{1000}$ of an inch of compression.

In regard to the curves for the smaller leads, $\frac{3}{10} \times .6$, $\frac{4}{10} \times .8$ and $\frac{5}{10} \times 1$, it will be noticed that the curves have a certain parallelism. The $\frac{3}{10}$ and $\frac{4}{10}$ curves nearly coincide, which shows that shortening the plug compensates, in a measure, for increasing the diameter. This appears from our general equation for cylindrical plugs,

$$x = \frac{KVy^a}{L - y};$$

for since $V = LA$, A being the area of top of plug,

$$x = \frac{KALy^a}{L - y},$$

which shows that the work is directly proportional to the original area of cross section, and, since L is greater than y, x is a decreasing function of L; that is, the shorter plug requires more work for equal compressions.

But we also see from the same equation that for plugs of a given diameter or area A, since L enters both numerator and denominator, that *small variations* in the length will affect the work very slightly, which is some comfort to a man who cuts his plugs in a miter box.

Now, in regard to the curve for the $\frac{3}{10}$ lead, if we assume that it is represented by the equation

$$x = \frac{KVy}{L - y} \text{ or } x = \frac{By}{L - y},$$

in which the exponent of y has been omitted and L is equal to 601, and substitute the values of x and y given in General Abbot's table (omitting values of x less than unity), and compute the corresponding values of B, we have the following:

Foot-pounds.	Compression $\frac{1}{1000}$ inch.		
$x = 2.496$	$y = 90$	$B = 14.2$	
$x = 5.612$	$y = 160$	$B = 15.5$	
$x = 9.932$	$y = 232$	$B = 15.7$	Mean $B = 15.1$,
$x = 15.460$	$y = 300$	$B = 15.5$	
$x = 22.090$	$y = 357$	$B = 15.1$	
$x = 29.870$	$y = 404$	$B = 14.5$	

from which we see that B is very nearly constant, and the curve for the $\frac{3}{10}$ lead can be quite accurately represented by the equation

$$x = \frac{15y}{601 - y}.$$

If we treat the curve for the $\frac{4}{10}$ lead the same way and calculate the values of B for the same values of x (neglecting those below 10), we will find B to vary between 31.7 and 36.5; in other words, y in the equation of this curve needs a very small exponent. For the

$\frac{5}{10}$ and $\frac{6}{10}$ curves we find B to increase a little faster. For the $\frac{75}{100}$ lead, using the equation

$$x = \frac{By}{1006 - y},$$

we find the values of B to increase pretty steadily from

$$x = 9.9, \quad y = 75, \quad B = 123,$$

to

$$x = 165, \quad y = 500, \quad B = 166.$$

From this discussion we see that the value of a, the exponent of y, in the equation

$$x = \frac{By^a}{L - y},$$

increases with the diameter of the plug; that it is about unity for the $\frac{3}{10}$ plug, probably less than unity for smaller sizes, and is about 1.1 for one-inch plugs.

Moreover, if we construct a logarithmic curve for each of these leads (as I have done, though they are omitted in the plates) from the equation $x = \log (1 - y)$, taking the length of the plug as unity, and assuming a modulus which will make the logarithmic curve coincide with the real curve for small values of y, we find that the fault of the logarithmic curve is that it is too nearly straight, that it lies between the real curve and the axis of Y, but that it agrees better with the real curve for the smaller leads than the larger. The inference is that there would only be coincidence for a lead indefinitely small, and, since the logarithmic curve is deduced under the hypothesis that the density of the plug remains constant during compression, we conclude that the density during compression increases the more rapidly as the diameter of the plug is greater.

If we now consider the curves (Plate II) for the $\frac{5}{10}$, $\frac{6}{10}$, and $\frac{75}{100}$ leads, which were all one inch in length, we see that they have not the parallelism of the $\frac{3}{10}$, $\frac{4}{10}$, and $\frac{5}{10}$ curves, but though they diverge, they are regular and consistent one with another, the plugs showing more work for the same compression in proportion to their size. To see how exactly this proportion holds, we will assume that for a given compression the work is proportional to the area presented to the hammer or piston.

If the density remained the same, this area would be proportional to the original area. Moreover, if in two plugs of different diameters but the same length the law of change in the density were the same—that is, the densities of the two were equal for equal compressions—the *works* would still be related as the original areas. If the leads are of equal hardness, this is implied in one general equation,

$$x = \frac{KALy^a}{L-y},$$

provided the value of a is independent of the diameter. Now, if we consider two plugs, such as the $\frac{6}{10}$ and $\frac{7.5}{10\,0}$, the law of change in the density would not be exactly the same. If we reflect that the density increases because the flow of the metal is retarded, we see that the density must increase more rapidly in the larger plug, and this for a given compression should show more work than its relative area calls for, a conclusion we had already arrived at in another way.

To illustrate this I have attempted to reduce the curve for the $\frac{5}{10}$ lead to that for a hypothetical $\frac{6}{10}$ lead by multiplying its values of x (foot-pounds) by 1.44, the ratio between the original sectional areas; also the $\frac{6}{10}$ curve to a hypothetical $\frac{7.5}{10\,0}$, by multiplying x by 1.56.

It will be seen that the agreement of the reduced curve in both cases with the original curve is very close for low compressions, but there is a difference for higher compressions, the real plug showing a little more work for the same compression. The divergence to the right of the curve for the real and larger plug is represented in one equation by a slight change in the exponent a, which, as we saw before, increases slightly with the diameter.

For the sake of comparison, I have plotted on Plate I the curve for General Abbot's $\frac{7.5}{10\,0}$ lead, and deduced from it the curve for a hypothetical one-inch plug by multiplying the values of x by 1.78. This hypothetical one-inch plug differs from a real one-inch plug made from the Abbot lead in the same way that the hypothetical $\frac{7.5}{10\,0}$ varied from the real plug of that size. If we had chosen to assume that the same law held, we could have drawn the curve for the real plug pretty accurately, but the hypothetical one answers our purpose. The conclusion is that the Abbot lead was softer than

mine, as it shows less work for the same compression. It was probably a very pure lead from one of the Galena ores, which is especially noted for purity. Mine was Selby lead, and contained a small percentage of hardening impurities, which did not affect, however, its fitness for the purpose. The superintendent of the Selby Smelting Works informed me that the impurities were small quantities of antimony and zinc. A San Francisco chemist of repute once told me that it carried also traces of silver.

Since the above was written I have tested some *pure* lead plugs, cut like the first from one-inch lead bar. Mr. Alfred Rupp, of the Selby Works, was kind enough to have the lead analyzed for me. He writes that it contains only *traces* of zinc and antimony.

I determined a short curve for these plugs by making a series of experiments with the foot-pounds machine. The curve, which is remarkably uniform, is plotted near the hypothetical curve for Abbot one-inch lead, and agrees with it very closely. It is also plotted in Plate II. By reasoning on the curves it is easy to see that this lead agrees very nearly in properties with the Abbot lead. It was probably a little softer than the Abbot.

We can sum up this part of the subject by saying that the relation between work and the compression of cylindrical lead plugs by a falling weight may be approximately represented by the general equation

$$x = \frac{KVy^a}{L - y},$$

in which K is a constant depending upon the nature of the lead, V the original volume, L the original length of the plug, and a a small exponent which increases slightly with the diameter.

It will be shown later that the *form* of this equation is incorrect, but the co-ordinates given by it are quite accurate, except near the origin.

The Anomalous Sub-Aqueous Action of Nitro-Glycerin.

Returning to consider General Abbot's work, we note his table of the relative intensities of action of various high explosives, which has been quoted so often that it has become classical. It is here given for a few of the most prominent explosives only. I have

added the relative energies calculated from the intensities by General Abbot's rule.

Explosive.	Action under water.	
	Relative intensity.	Relative energy.
Dynamite,	100	100
Explosive Gelatine ('81),	117	126
" " ('84),	142	169
Forcite,	133	153
Dualin,	111	117
Hercules No. 1,	106	109
Gun-cotton,	87	81
Mica Powder No. 1,	83	76
Nitro-glycerin,	81	73
Mica Powder No. 2,	62	49

It must be noted that these relative intensities are taken horizontally. General Abbot also gives (p. 110) the relative intensities taken vertically upward and downward, dynamite being again taken as the standard. Lieut.-Col. J. P. Farley, of the Ordnance Department, in a recent paper, "Compilation of Facts Relating to High Explosives," published in the Journal of the Military Service Institute, November, 1891, falls into a serious error in commenting upon General Abbot's work in the following sentence: "It has been shown experimentally that the forces developed by a subaqueous explosion indicate that the normal line of maximum intensity will be directed downward," whereas the maximum effect is upward. Colonel Farley was probably misled by the table on page 110, in which dynamite is taken as 100 in all three directions, the numbers in each column being relative only to themselves, but it is shown by the context and pictorially by Plate XIV that its action is fifty per cent. greater upwards than downwards. This error, which is probably nothing more than the slip of a pen on the part of Colonel Farley, is mischievous, because it tends to confirm a foolish notion firmly rooted in the minds of miners and other practical men that high explosives have some special property of acting downwards. This table is very instructive, as it shows a greater relative efficiency downward for the more intense acting explosives. To illustrate, dualin, which gives 111 compared with dynamite horizontally, gives 116 compared with it downward (really 68 compared with its own upward action, and 80 with its own horizontal action

taken as 100). Hercules gives 106 horizontally and 109 downwards. Explosive gelatine (1881) 117 horizontally and 125 downwards. (The downward action of dynamite is 64 compared with its upward action, and 77 compared with its horizontal action.) General Abbot appropriately remarks: "The greater the resistance to be overcome the more distinctly marked are the differences between the intensity of action of the several explosive agents. In other words, the most severe test of their relative power under water is their action vertically downward. As the work required of them in submarine mining, however, varies from the horizontal plane upward, their relative horizontal action appears to be the true criterion."

It is a remarkable fact that nitro-glycerin should stand so low in this scale—81 compared with 100 for dynamite. Its action downward shows a still more startling difference—71 against 100 for dynamite.

This anomal is certainly very surprising, as it is generally acknowledged that nitro-glycerin in rock blasting does at least $\frac{4}{5}$ as much work under similar conditions of confinement as dynamite, or, in other words, gives the result naturally expected of it. Dynamite consists of 75 per cent. nitro-glycerin and 25 per cent. of an inert absorbent, kieselgühr, which cannot be expected to add to the strength of the explosive, and yet, according to General Abbot, in sub-aqueous explosion the intensity of action of nitro-glycerin is only about $\frac{8}{10}$ that of dynamite or $\frac{6}{10}$ of what we would naturally expect.* "A part seems to be greater than the whole," to adopt an expression which the late impetuous Geo. M. Mowbray was wont to use in confounding the rivals of his tri-nitro-glycerin, and yet no one who reads General Abbot's Report can doubt for a moment that his rating of nitro-glycerin is a "fact." We may differ in interpreting his results, but the results must be accepted.

This anomaly receives an incidental discussion in a paper entitled "Explosives and Ordnance Material," by Mr. S. A. Emmens, published in the Proceedings of the U. S. Naval Institute, No. 59, 1891. The paper is very entertaining, and furnishes much food for thought. Mr. Emmens gives General Abbot's theory as summarized by Pro-

*This is only rough reasoning. The real discrepancy is larger. General Abbot uses mean intensity of action as a measure. If he had used work—quantity of action—the figure for nitro-glycerin would have been about 73, not quite 55 per cent. of normal—133.

fessor Munroe, which (p. 110, "Submarine Mines,") is thus given by General Abbot himself: "Dynamite No. 1 is simply nitro-glycerin granulated. With gunpowder granulation promotes intensity of action by opening passages for the initial flame to permeate the mass and thus accelerate the formation of the gases. Were this the true explanation of the phenomenon in question, a similar relative strength between the two explosives would also be shown in rock blasting, which is contrary to observation, as nitro-glycerin in hard rock is admitted to be by far the stronger of the two. Let us suppose, on the other hand, that granulating nitro-glycerin by absorbing it in kieselgühr has precisely the contrary effect, *i. e.* that the particles of silica slightly retard chemical action, as is not unlikely, since in detonation the reactions may occur within the molecules. This idea appears to me to supply the required explanation; for the resistance opposed by water, being of a slightly yielding character, may exact more time than is afforded by nitro-glycerin pure and simple. I regard this as the most plausible explanation of a fact which, although novel, is so well established by my experiments that its correctness can hardly be questioned."

Mr. Emmens takes issue with General Abbot, and objects to the nitro-glycerin in dynamite being considered granulated, because "careful inspection shows no interruption of liquid continuity in the nitro-glycerin constituent of dynamite." One might interpret this sentence to mean that the dynamite consists of a continuous liquid with the solid suspended in it. The dynamite would then be almost incompressible and as sensitive as the liquid itself, but no such meaning was intended. I examined with a powerful microscope two varieties of dynamite—one, Nobel's, made in Scotland; the other made by myself from German kieselgühr. Under the microscope, although there is a marked granulation, the liquid appears to predominate much more than to the naked eye. The appearance by transmitted light is something like a pile of dirty snowballs. In the sense that every particle of the liquid at certain points touches other particles, or, in other words, that there is no particle completely isolated from its fellows, I think Mr. Emmens is right.

He then makes this point: "Moreover, the reference made by Professor Munroe to certain dynamites 'which are made so as to explode with exceeding rapidity, and which fall very low in the scale,' is not borne out by the best-known of such quick-action

dynamites, viz., Mowbray's mica powder. No. 1 grade of this powder, containing only 52 per cent. of nitro-glycerin, gave a force of 102, as compared with 100 for pure nitro-glycerin."

Of course Professor Munroe's comparison, based on General Abbot's views, was with dynamite. Nitro-glycerin itself is low in the scale.

Still Mr. Emmens' point is well taken. If quickness were a cause of failure, why should quick mica powder give 83 compared with 100 for dynamite, when it contained only $\frac{79}{100}$ as much explosive matter? A part of this discrepancy disappears if we compare the energies instead of intensities—100 : 76 instead of 100 : 83. Another answer to the riddle is that there is no *proof* that mica powder was specially quick, except the dictum of Mowbray, which General Abbot gives without endorsement, but to which he attaches too much importance. It must be remembered that Mowbray was sued for infringement of the dynamite patent by the Atlantic Giant Powder Company, and he was cudgelling his brain for some point upon which to hang a specific difference. Mica powder, in the opinion of fair-minded, practical men, was a bold infringement of Nobel's invention; but Mowbray made a gallant fight, which consisted of unflinching assertions based upon *à priori* reasoning.

Mr. Emmens solves the problem by his "Ballistic Theory of Explosives," which is based upon the kinetic theory of gases, according to which the pressure of a gas upon the walls of its containing vessel is caused by impacts of the gaseous molecules upon the walls. The *vis viva*, or energy, of the molecules has two factors —mass and velocity. "The character of the blow as regards the effect produced upon the body struck must be different in the cases of two projectiles, one of which (say a molecule of carbonic anhydride) weighs 22 times as much as the other (say a molecule of hydrogen), even though the energies of the two blows be equal." He then illustrates his theory by a proximate calculation of the factors mass and velocity in the case of nitro-glycerin and dynamite. We have no exception to take in the case of nitro-glycerin. He first calculates the volume of gases produced by 1000 grammes of nitro-glycerin (reduced to 0° C. and 760 m.m. of mercury), then the temperature of the gases, then the volume due to this temperature, and finds this quantity 18,738.7 liters. He then proceeds as follows: "But if the nitro-glycerin be confined in a shell, for

example, then 18,738.7 liters would be compressed within the space of $\frac{1}{1.6}$ liters, and therefore would press upon the walls of the shell with a force equal to $18{,}738.7 \times \frac{1}{1}^{.6} = 29{,}981.9$ atmospheres. The mass being 1000 grammes, the velocity factor may be taken as $\frac{29981.9}{1000} = 29.9819$." I think no one can take exception to this reasoning, but when it comes to dynamite the case is different. Having calculated the elements as before, he finds the expanded volume of the gases 10,861 liters and "the silica expanded 20.05 cubic centimeters in excess of its original volume. But if the explosion took place in a close vessel, the space available for the gases would be $\frac{1}{1.6} \times \frac{3}{4} - 20.05 = .4487$ liters, and the pressure would therefore be $\frac{10861}{.4487} = 24{,}205.5$ atmospheres. The mass factor of this pressure is 750 (as the dynamite gases have but .75 of the weight of the gases produced by 1000 grammes of nitro-glycerin) and the velocity factor is $\frac{24205.5}{750} = 32.27$." I hold that this calculation is open to such serious criticism as to impair the conclusion in its general application to dynamite. It is plain to see that this result is a question of density of loading.

For nitro-glycerin this is properly assumed as 1.6, and the 1000 grammes of products occupy $\frac{1}{1.6} \times 1000 = .625$ liters, while for dynamite, as the space available for the gases is only .4487 liters—if we take into account the loss of space by expansion of the silica—the original space allowed was .46875 liters, corresponding to a density of 2.13 for the dynamite. The density of the dynamite compacted into cartridges is 1.4. It appears, therefore, that Mr. Emmens' calculation applies only to a theoretical case which cannot be realized in its essential conditions.

As to the effect of density of loading in General Abbot's experiments, the latter show that within wide limits his results are independent of it. If it be contended that Mr. Emmens' reasoning is strictly theoretical and based upon ideal conditions, the answer is that it is offered as the explanation of a practical problem—the anomalous action of nitro-glycerin and dynamite in sub-aqueous explosion. General Abbot has shown that a void, as he calls it in his table, of three times the volume of the charge does not affect the registered energies of dynamite.

If Mr. Emmens is right, the presence of the inert matter in dynamite gives additional velocity to the molecules of the gases, whereas one would naturally think that it would impede their motion slightly.

This latter idea is borne out by tests with the crusher gauge, made by Drinker himself. (See "Tunneling, Explosive Compounds and Rock Drills," pages 78 and 79.)

"The second trial was to test whether in ordinary No. 1 dynamite (or giant powder), composed of 75 per cent. of nitro-glycerin and 25 per cent. infusorial earth, there was any appreciable loss of power by the absorption of the nitro-glycerin in the infusorial earth.

"(*a*) Charge 1.5 grammes No. 1 dynamite.

Mean height of leads before firing,	.932"
" " " after "	.194"
compression	.738"

"Next the amount of pure nitro-glycerin combined in 1.5 grammes No. 1 dynamite was taken.

"(*b*) Charge 75 per cent. of 1.5 grammes=1.125 grammes nitro-glycerin.

Mean height of leads before firing,	.933"
" " " after "	.180"
compression	.753"

"Therefore

"(*c*) Compression exerted by No. 1 dynamite,	.738"
" " " nitro-glycerin alone,	.753"
In favor of nitro-glycerin alone,	.015"

"This difference is very small; still it would appear sufficient to indicate, if not a *practical*, still a positive and *appreciable* diminution of the effective power of the nitro-glycerin by the absorbent." This small difference, .015", is the less insignificant on account of the conical shape of Drinker's plugs. The comparison, it must be noted, is between a certain weight of dynamite and three-fourths of the same weight of nitro-glycerin.

I have repeated Drinker's experiment several times, and have also varied it slightly by taking the weight of the nitro-glycerin as a fixed quantity. I first fired 24 grains of nitro-glycerin and noted the compression. To a second charge of 24 grains, weighed and placed in the cavity of piston, I added 8 grains of kieselgühr,

which I mixed carefully with the point of a knife. In every case I have confirmed Drinker's conclusions.*

To resume, Mr. Emmens finds that the ratio $\frac{29}{8}:\frac{28}{2.27}$ between the velocity factors which he has calculated for nitro-glycerin and dynamite, agrees fairly well with the intensity ratio observed in the course of General Abbot's experiments, certain allowances being made. We have shown, we think, that no credence is to be given to the figure 32.27 as applied to dynamite.

He goes on to compare the figures with those of Lieutenant Walke's recent experiments, but in this he falls into a grave error. Lieutenant Walke expressly explains that his compressions are not to be assumed as direct measures of either energy or intensity, and in arranging his table he is careful to use the expression "*order* of strength." Nevertheless Mr. Emmens treats the figures representing the order of strengths (which are directly proportional to the compressions, taking the compression for nitro-glycerin as 100) as energy measures, so that his reasoning on them is vitiated. There is a hopeless confusion in all this of energy or quantity of action with intensity of action.

But if Mr. Emmens' theory is wrong, how is the anomaly, which he aptly calls the "Abbot effect," to be explained?

If we admit that the shock of nitro-glycerin is greater than the shock of dynamite, which is a fair general assumption, and yet we find that the effect of the shock transmitted through water is the greater for dynamite, one of two things must be true: either there was

*In the same series of experiments I tried the effect of a variety of substances by adding 8 grains of each to the regular charge of nitro-glycerin—an interesting investigation, the results of which were briefly as follows: Nearly all the substances tried showed an *increase* of compression, except inert mineral *absorbents*. The better the absorbent the greater the falling off in the compression. Clean, sharp sand is neutral, or nearly so. Overburnt charcoal shows a slight increase; underburnt charcoal has greater effect; bituminous coal still greater. Water shows a very great increase, due partly to tamping action, as it floats on the top of the nitro-glycerin; but even when divided up by using 4 grains of wood pulp and 4 grains water, it still shows a considerable effect, nearly equal to the wood pulp alone. The substances giving the greatest effect are wood pulp, fine sawdust or other vegetable fibre, pulverized sugars, starches, bituminous coals, anhydrous oxalic acid, paraffin wax, petroleum oils, etc.

The conclusion I arrived at was that the increase in some cases was partly due to the oxidizing effect of the surplus oxygen in the nitro-glycerin (as in the case of the charcoal), but generally and chiefly to the production of additional amounts of gas.

In the case of the sand, the union is not close enough to have any effect.

In the case of inert absorbents like kieselgühr, the heat and motion are shared with the solid particles without compensation.

In the case of organic absorbents and other active substances, the heat and motion are shared, but this is more than compensated for by the production of additional gas. The subject, however, is too large to be fully discussed in a foot-note.

something in the conditions to vitiate our premises in regard to the relative intensities of the initial shocks, or the whole shock has not been *transmitted* in the case of nitro-glycerin, part of the energy being lost in the medium. The second horn of the dilemma is the one which General Abbot accepts, in saying that the "resistance of water, being slightly yielding, may exact more time than is afforded by nitro-glycerin." But we will consider the other first. The only condition which could vitiate our premises is a loss of part of the nitro-glycerin, that is, the whole charge is not exploded.

This view is more worthy of consideration than appears at first blush. Perhaps the liquid condition of the explosive (for nitro-glycerin is singular in being the greatest anomaly in the table as well as the only liquid), in presenting an almost incompressible medium for the transmission of pressure to the containing case, may offer an explanation. Is it possible that the initial shock, set up by the detonator, could burst the case (usually an open tin can or glass bottle) before the whole body of the liquid charge exploded? This gives rise to a number of interesting questions. Is there an *explosive* wave independent of the *pressure* wave? If so, has one greater velocity than the other? If we can rely upon certain English experiments, both questions may be answered, I think, in the affirmative. In this connection we cite the attempts of Captain Nobel, in England, to measure the velocity of detonation of dynamite, gun-cotton and nitro-glycerin. I have no record at hand except a scant memorandum, but if my recollection does not play me false he found the velocity for dry gun-cotton to be about 17,000 to 18,000 feet a second, the velocity for dynamite about the same, and the velocity for wet gun-cotton 18,000 to 21,000 feet a second. These explosives were fired in long paper cylinders. For liquid nitro-glycerin in V-shaped wooden troughs he found the velocity about 5000 feet a second.

The velocity of the pressure wave is simply the velocity of sound. Liquid nitro-glycerin would transmit sound much more rapidly than a heterogeneous, inelastic mixture like dynamite. We may then say that nitro-glycerin transmits pressure to the case very rapidly, while the detonation proceeds slowly, and dynamite transmits pressure very slowly while the detonation proceeds rapidly.

Contrary to general belief, the explosion of nitro-glycerin or even dynamite, though rapid, is by no means instantaneous. If a cart-

ridge of dynamite is placed on end on an iron plate and fired with a detonator at the top end, the effect is greater than if the detonator be placed at the lower end. If the detonation were instantaneous, the effects would be the same. Being progressive, the action is easily explained. This being granted—that time is a necessary element in detonation—there are facts which seem to show that special conditions are required to insure the *complete* explosion of nitro-glycerin and its compounds.

Mowbray noticed at the Hoosac Tunnel that weak detonators did not fully explode his charges of nitro-glycerin—a part was blown out in vapor. In mining with dynamite the atmosphere of the drift often becomes laden with the vapor of nitro-glycerin, giving tyros and even experienced miners the characteristic headache. (See article by Dr. Darlington, of Arizona, in the Scientific American Supplement No. 786, January 24, 1891, republished from the Medical Record.) This effect is a general complaint against nitro-glycerin preparations, and is *not usually attributable to weak detonators* but to improper loading. In rock blasting it can be prevented, in my opinion, by careful loading, proper placing of the detonator, and good tamping.

Returning to consider our charge of nitro-glycerin in the tin can or glass bottle, if we admit the possibility of some portions of the liquid escaping from the case before they are exploded, the conditions are right to preserve these particles from subsequent explosion. Being finally divided by the blow which scatters them, they would form instantly an emulsion with the surrounding water, and thus be protected. In support of the protection afforded by this condition, I can cite some facts from my own experience. It has been my fortune to inspect, immediately after the accident, the ruins of several nitro-glycerin explosions, where tons of the liquid went off, creating havoc with buildings, lead vats, and, unfortunately, sometimes with human bodies. One would naturally suppose that not a particle of nitro-glycerin within a radius of fifty feet would escape explosion. Buckets of the liquid one hundred and fifty feet away have been known to explode by "sympathy," blowing the Chinaman who was carrying them to pieces. Yet, when the ruins are overhauled, men handling the timber and litter get violent headaches, showing the presence of the liquid—in fact, it has been found in considerable quantity among the débris. The explanation is that this liquid

was at the time of the explosion an emulsion with either water or acid.*

The only strong argument against my suggested theory of a loss of nitro-glycerin is that the acute experimenters handling and firing many charges should have given it no countenance. However, General Abbot's experiments were made a good many years ago, when simpler views prevailed in regard to detonation, and nitro-glycerin was believed to be the quickest of explosives.

We will now consider his own explanation—a loss of energy in the medium transmitting the shock. If we admit that the liquid is all exploded and that its shock or initial energy is greater than that of dynamite, and yet when we measure the energies transmitted to the plugs through a foot or more of water, we find the dynamite registering more than the nitro-glycerin, the conclusion is inevitable that the intervening water has absorbed some of the energy, and the relative quantity absorbed is greater in the case of the nitro-glycerin than in the case of the dynamite; in other words, the water has been heated more by the nitro-glycerin.

If the water were incompressible it would transmit the energy in both cases without diminution (except by the law of the square of the distance). Being compressible, if it were perfectly elastic, it would still transmit the energy undiminished in the ideal case, the heat of compression being balanced by the cold of expansion. Water for the purposes of this discussion *may be regarded as perfectly elastic*, and any *confined* portion of it will transmit energy undiminished. The law of its heating by compression was experimentally determined by Joule. If the heat is not allowed to leave it, it regains its original volume and temperature when the pressure is removed. In General Abbot's experiments the water was not confined, and part of the heat of compression may have been dissipated beyond the orbit of his registering plugs. We may suppose the relative loss was greater in the case of nitro-glycerin than dynamite. On this slender thread it seems to me his theory hangs.

*A charge of about 1700 pounds of nitro-glycerin, agitated in a lead "nitrator" or "mixer" with about four times its weight of acid, has been known to withstand the shock of nearly a ton of the liquid exploding within four feet of it. The mixer, with its lead coils still in it, torn from its foundations, thrown perhaps twenty feet and crushed into a shapeless mass, showed no signs of an explosion inside.

An equally perfect agitation with half as much water (as acid) would probably have the same protecting effect, the protecting effect being a question of specific heat.

Although I have held these theoretical views for a long time, it is only lately that I have attempted to test them by a practical experiment. My object was to prove whether or not there was anything in the nature of water which rendered it a better medium for transmitting the shock of dynamite than for transmitting the shock of nitro-glycerin. To the instrument designed for this purpose I have given the name "water crusher gauge."

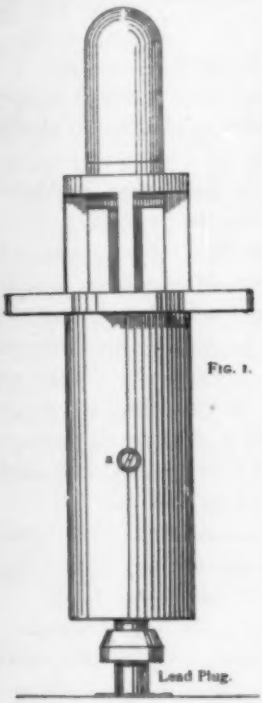


FIG. 1.

FIG. 2.
Section of Pistons and Shot.

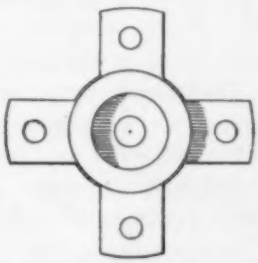


FIG. 4.—Top View. Shot and Piston removed.

FIG. 3.

WATER CRUSHER GAUGE.

This instrument consists of a brass cylinder 4 inches in outside diameter, with a bore-hole exactly one inch in diameter. The extreme length is 14½ inches; 3¾ inches below the top are projecting lugs to rest on the ring of the Quinan gauge, to which they are firmly bolted. This brings the cylinder inside of the slides, the lower end being about 2½ inches above the steel block, upon which the lead plugs are crushed. Above the lugs the brass cylinder be-

comes a skeleton support and guide for the piston, and consists of a ring and four upright guides.

The pistons are of steel. The top piston has a total length of 6½ inches. The lower part, 1 inch in diameter and 5 inches long, is fitted to the bore of the cylinder. The upper part, 2½ inches in diameter, is fitted to slide between the guides and through the brass ring. The powder cavity is small, 1 inch in diameter and ⅜ inch deep. The lower piston is shorter, the portion fitted to the bore of the cylinder being 2½ inches long.

The shot is 5 inches long and 2½ inches in diameter.

The instrument is designed to transmit the blow through a column of water enclosed between the two pistons. The length of the column of water used was 6 inches.

The apparatus was so well made that the pistons were air-tight. When one was pushed in, the other was pushed out by the air.

In operating it, the lower piston was carefully oiled and inserted in place, and the cylinder bolted to the ring of the large crusher gauge. The lead plug was placed under the lower piston, and the bore-hole filled with water, the gauge being brought to the perpendicular for the purpose. The top piston, carefully oiled, was then entered. The small screw *a* on the side of the cylinder which communicates by a ⅛ inch hole with the bore, was then loosened, and enough water drawn off to allow the top piston to descend until exactly 6 inches of the column of water remained in the cylinder. The screw was then driven in tight with a screw-driver. The charge of explosive was placed in the cavity, the shot, with capped fuse already inserted in it, was placed on top, and the charge fired.

Castor oil was used to lubricate the pistons. During the experiments it was found advisable to support the top piston at the exact point by placing upright under it a piece of pine wood about the size of a parlor match, as the screw leaked slightly, unless driven home very hard, and allowed the piston to descend too far, especially when the weight was increased by putting on the shot.

The only defect developed during the trials was that the steel had not been tempered sufficiently hard. The cavity in the top piston became roughened by the gases and the fuse-hole in the shot considerably enlarged, which caused a falling off in the apparent strength of the different explosives; but as these were made to alternate in the firings, and a comparison only was aimed at, the defect was not serious.

The weights of the moving parts were as follows:

Weight of shot,	90	ounces.	
" " top piston	50	"	} 73.73 ounces.
" " lower "	21	"	
" " water	2.73	"	
" " middle piston, 5 ounces (to be described later).			

The compressions were reduced to foot-pounds by the curve for soft lead plugs on Plate II, which curve was determined specially for these plugs.

The uniform charge selected was 10 grains, a small charge, but the delicate nature of the apparatus seemed to prohibit a very heavy shock. It will be seen that during the experiments it received such a shock and stood it very well.

The detonator used was a triple force cap, supposed to contain, beside fulminate, a small per cent. of gun-cotton. The caps were not as uniform as could be wished. In tne preliminary experiments, made to determine their strength, the compression ranged from 104 to 132. The mean work of the cap was taken at 30 foot-pounds.

The experiments were as follows, it being understood that the tests were not in the order given, the results for each explosive being segregated:

Nitro-glycerin.—Anhydrous, several months old, charge 10 grains.

	Compression in $\frac{1}{1000}$ inch.	Foot-pounds.	Foot-pounds corrected for cap.	
	379	183	153	
	381	184	154	
Shot No. 6	669	600	570	anomalous, rejected.
	377	180	150	
	369	173	143	
		Mean work,	150	

Dynamite.—The dynamite was made from the same nitro-glycerin and German kieselgühr, 75 per cent. of the former and 25 per cent. of the latter, charge 10 grains.

Compression.	Foot-pounds.	Foot-pounds corrected.
336	147	117
323	137	107
308	127	97
310	129	99
	Mean work,	105

Ratio of mean work of dynamite to mean work of nitro-glycerine, $\frac{105}{150} = 70$ per cent.

Gun-cotton.—This was a very strong explosive, made by nitrating a fine hydrocellulose, which was obtained from cotton-waste. The gun-cotton was in fine powder, charge 10 grains.

Compression.	Foot-pounds.	Foot-pounds corrected.
312	130	100
310	129	99
	Mean work,	99.5

Ratio of work of gun-cotton to work of nitro-glycerin $\frac{99.5}{150} = 66.3$ per cent.

This is probably low, as the gun-cotton was tried after the gauge had suffered some deterioration.

The ratio 70 per cent. for dynamite and nitro-glycerin, though a little low, is the ordinary crusher gauge effect, which, as proved by many experiments (including those of Drinker, already referred to) shows a strength for dynamite a little less than that due to the contained nitro-glycerin.

To test this anew, the water gauge was converted into an ordinary gauge by dispensing with the water column, and inserting between the two pistons the piece of steel shown in Fig. 3. This was made as light as possible, so as to approximate the weight of water for which it was substituted. It weighed really 5 ounces instead of 2.73, making the relative weights of the shot and compound piston 90 : 76 instead of 90 : 74, as in the water gauge.

This change had a slight effect in lessening the compression probably, but the compression was still more reduced by the lack of continuity in the compound piston. In these experiments, the middle piston being only 3¾ inches long, I used a steel plate ½ inch thick under the lead plug, and the joint between the top piston and the shot in the firing position came *below* the brass ring of the cylinder.

The caps were tried again, and their mean work averaged at 32 foot-pounds.

Nitro-glycerin.—Same as before, charge 10 grains, all steel compound piston.

Compression.	Foot-pounds.	Foot-pounds corrected.
346	156	124
321	136	104
	Mean work,	114

Dynamite.—Same as before, charge 10 grains, all steel compound piston.

Compression.	Foot-pounds.	Foot-pounds corrected.
298	120	88
280	108	76
	Mean work,	82

Ratio of work of dynamite to work of nitro-glycerin $= \frac{82}{114} =$ 71.9 per cent. This agrees well with experiments in the large gauge.

Gun-cotton.—Same as before, only one shot was fired with gun-cotton, charge 10 grains, all steel compound piston.

Compression.	Foot-pounds.	Foot-pounds corrected.
305	124	92

Ratio of work of gun-cotton to work of nitro-glycerin $= \frac{92}{114.5} =$ 80 per cent.

This is too large, but agrees fairly well with tests of this gun-cotton in the large crusher gauge.

The following observations were made with the water gauge: Sometimes both pistons rebounded slightly, and the lower piston was found a half inch or so above the lead. Usually the lower piston was found in contact with the lead. No loss of water could be detected by measuring the column of water, including the lengths of the pistons immediately after firing. No increase in the temperature of the water could be detected.

Shot No. 6 with nitro-glycerin is to be explained in this way. The proper firing position for the top piston is shown in the sketch. The joint between the piston and shot should be about $\frac{3}{8}$ inch *above* the brass ring of the cylinder. In this shot the screw was not driven in tight, and when the shot was put in place the piston slowly sank during the burning of the fuse till the joint came well down in the ring. When the charge was fired the gauge was converted for the moment into a mortar, the gases being confined by the tight-fitting ring. The weight of the compound piston was also lessened by the

loss of water, but the influence of this was slight compared to the mortar effect of the ring. The result of the shot was the tremendous compression of the plug as shown, but this gives only a faint idea of the exhibition of power. The shot was thrown probably 40 feet into the air, *and was followed an instant or two later* by the top piston, which was thrown still higher, and fell at least a half second after the shot. Part of the water was also thrown out in a jet. The actual compression of the water must have been considerable to produce such effects. Unfortunately it was not measured.

In discussing the experiments with the water-crusher gauge, we think we are justified in saying that *there is nothing in the nature of water which makes it a better medium for transmitting the energy of dynamite than for transmitting the energy of nitro-glycerin.* It is not claimed that the conditions of explosion were the same as in General Abbot's experiments. I employed a *confined column* of water, acted upon by a steel piston of considerable weight. Under these conditions water seems to transmit the whole force of nitro-glycerin. It is undoubtedly compressed and heated, but the subsequent expansion and cooling restores the energy without sensible loss. If the experiment could have been conducted with a piston without weight, the expansion of the water might not have made this compensation, although there is no reason to believe that this would have been to the advantage of dynamite. In this case, if the explosive were quick enough to complete its work and then condense before the phase of water expansion set in, the expansion would be without effect on the plug. In my experiments the inertia of the piston served to make the expansion of the water contribute its quota to the crushing of the plug. In one experiment only, No. 6, did the inertia of the piston appear to be inadequate. In this instance a portion of the energy imparted to the water was not transmitted to the plug, but was expended by the rebound in projectile force.

Too much importance, however, must not be attached to this difference between my conditions and those of General Abbot. It is true, the blow of his charge was partly transmitted by water without the intervention of a block of steel having considerable weight (his piston being insignificant in this regard), but it must be remembered that his charges were incomparably larger, that they consumed a much larger interval of time in evolving their gases, and that the water acting upon the piston had in rear of it the sustaining

pressure of these gases, which must have acted somewhat like the inertia of my piston in directing the expansive force of the water, and, lastly, it must be noted that, at least in his larger charges, *his piston must have been acted upon directly by the gases themselves* for at least a portion of the period of explosion. The globe of gas must have extended far beyond the orbit of the plugs in some, if not all, of his charges.

The more the subject is considered the more strange the anomalous action of nitro-glycerin becomes, unless we adopt some very simple explanation, such as the loss of a portion of the charge in the surrounding water.

If this theory is correct the loss results from the incompressible nature of the liquid. There being no chance for expansion, the case is burst before the whole of the liquid is converted into gas, whereas with dynamite the interstitial spaces give a little time for this conversion before the pressure bursts the case. This theory could be easily tested. Divide the charge of nitro-glycerin among a number of very small, thin, glass bottles, the bottles being tared to get the weight of liquid. Fill each bottle not more than half full. Pack the bottles loosely into a strong case, using one as a primer. This experiment has the advantage of being perfectly feasible. If it gives a largely increased intensity of action for nitro-glycerin, we may regard the theory as proved. If it does not, then we have thrown no light upon the subject, and must "guess again."

Lead as a Register of Work.

Lead has a good deal to recommend it as a material to register work. In the first place, it is very sensitive; secondly, a plug already partly compressed will register a second blow very accurately, the work corresponding to the second blow being equal to the work corresponding to the total compression, less that belonging to the first compression; or, if the plug retains the cylindrical form after the first compression, we can treat it as a new plug of larger diameter and shorter length with a curve of its own.

General Abbot notices this valuable property of lead, and makes use of it in his experiments (see page 138 of his Report).

I have made some special experiments to test the accuracy of the principle in the foot-pounds machine, and found it quite reliable through a wide range of compressions.

The question whether the work indicated by a given compression in the foot-pounds machine is exactly equal to the work corresponding to the same compression by an explosive in the crusher gauge has been mooted before. That it is approximately the same I have no doubt, but there are good reasons for believing that the agreement is not generally exact. If the two compressed plugs show the same form, we are entitled to think that the same resistance was developed, and in the same way. In my experience there is less difference in form when the lead is hard, and I therefore regard this material as the best. Soft plugs are more regular in form when compressed by a falling weight than by an explosive. When compressed by a weight they are cylindrical for small compressions and barrel-shaped for great compressions, the top and bottom remaining equal, or nearly so, in area. When the plug is compressed by a high explosive, the higher compressions are tub-shaped.

This difference of form implies a difference in the law of the resistance, and probably a difference in the amount of work. The most plausible explanation of this difference of form that occurs to me is a difference in the law of action.

In the case of the falling weight the first part of the compression is done rapidly; the action is a maximum at the beginning and decreases by a regular law. In the case of the high explosive the action begins as zero and rises to a maximum, and then falls to zero again. If the maximum is very near the close of the action, there may not be time for the flow of the metal to be equalized. The heat developed by the blow *softens the top part of the plug, which consequently spreads faster than the bottom.*

The same effect takes place with the falling weight at or near the beginning, but the effect is masked by the subsequent compression. Whether or not the *total time* of action is greater or less in the case of the explosive or the falling weight is a nice question.

General Abbot concluded, in his experiments, that the action of the pendulum hammer was much shorter in period than his high explosives. This might well be, as his charges were incomparably larger than crusher gauge charges and acted through a foot or more of water, whereas in the crusher gauge, from the arrangement of parts and the smallness of the charge, the time required to detonate the charge and complete its action on the plug must be very short; nevertheless, we believe the hammer or weight was quicker in its action in

performing the same work, for the simple reason that it begins its action as a maximum, whereas every explosive must begin as zero and develop its maximum action during the course of the work. We regard the *hammer action as a limit which explosives may approximate but can never reach.* This is not a rigorous demonstration, however, and I only offer it for what it is worth. We will touch upon this subject again.

A question allied to the one we have been discussing, viz., the equality between work by a falling weight and work by an explosive, is this: Is the compression by a falling weight the same for a given number of foot-pounds whether the latter be made up of many feet and few pounds or few feet and many pounds?

This it was easy to decide in the affirmative for at least *the range of the apparatus* by a few experiments in the foot-pounds machine.

Copper as a Register.

There is another metal used to register the effects of forces in crusher guages—copper. The parent form of the instrument was Rodman's indenting piston and copper disc. When Rodman first proposed this for measuring the powder pressure in guns, the theory of its operation was criticised by Professor Bartlett, of West Point. The practical usefulness of the Rodman guage has been proved by many years' experience. Any error in the theory of its application affects equally the crusher form of the apparatus. The quantity aimed at in gun experiments is the maximum pressure or the maximum intensity of action, supposed to be represented by the final resistance to either the cutter or the crusher piston. The scale of pressures (that is, the reading for the cuts or compressions) is determined in our service, and I think also in Europe, by a testing machine sometimes called erroneously a dynamometer, a simple arrangement for weighing the pressure which is applied by a screw to the copper cylinder or discs. The staging supporting the copper is connected with a system of levers, one of which has a sliding weight to counterbalance and measure the pressure. It is assumed to be a fact with copper of a given quality that if the screw be driven *slowly*, the length of the cut of the indenting tool or compression of the cylinder is practically the same for the same pressure. When a certain cut or a certain compression has been made, the disc or cylinder can be replaced in the apparatus, and the same pressure applied without increasing either cut or

compression, provided it is applied slowly. General Abbot quotes the experience of English artillerists who found that a copper cylinder, compressed by a charge of gunpowder in a 12.5-inch gun, retained its reduced length unaltered, when the trial was repeated several times. The powder was a slow-burning, large-grain, 1.5-inch cubical. With lead, however, the case is quite different. Small pressures maintained for considerable periods produce the same results as larger pressures for shorter periods. For this reason General Abbot found it impossible to prepare a reliable scale for his plugs with the Rodman testing machine.

This difference of the two metals, notwithstanding that the practice of artillery experts may be properly based upon it, must be one of degree, due to the great difference in hardness, so that the above statements in regard to copper are to be received cautiously. In view of the fact that the resistance offered by lead is so susceptible to the influence of time, we may assume that copper resistance is not altogether independent of it. The use of the scale so determined to measure the effects of powder charges in guns has been criticised upon the general grounds that the action of explosives is analogous to a blow, and that ordnance experts confuse static and dynamic effects in treating this action as a pressure. Without giving any opinion at present upon the validity of this criticism, we may say one thing seems evident—the cut made by the indenting tool or compression by the piston, whether done in the testing machine or in a gun, is a register of *work*.

Dynamic Treatment of Copper.

I have, therefore, thought it well to treat some copper cylinders in the same way as lead plugs in the foot-pounds machine, and to determine the relation between the work and compression. Having these quantities, the mean resistance is easily obtained by dividing the work expressed in foot-pounds by the compression expressed in feet. This quantity, however, is not what ordnance experts aim at. For their purposes the crucial quantity is the maximum intensity or pressure, supposed to be represented by the maximum resistance of the copper. This we are not so certain of, but will do our best to determine also.

The cylinders were obtained from the Benicia Arsenal. They were .25-inch diameter and .5 inch long. Captain Rockwell, of the

Ordnance Department, had the following scale of pressures determined for me on the testing machine:

Measured Pressures Corresponding to Compression of Copper Cylinders, ¼" x ½".

Original length.	Reduced length. Inches.	Compression. Inches.	Pressure. Lbs. on the sq. inch.
.502	.420	.080	21,250
	.412	.090	25,000
	.392	.110	27,500
	.383	.119	30,000
	.370	.132	32,500
	.352	.150	35,000

As a preliminary to my experiments, I prepared a number of weights bearing simple relations to each other, as follows: I took a piece of steel shafting, exactly 2 inches in diameter, and cut it up in a lathe into cylinders 24, 12, 8, 4, and 2 inches in length. I also built a foot-pounds machine specially for these weights.

For my first set of experiments in the foot-pounds apparatus, I selected as my weight the piece of 2-inch steel shafting, 8 inches long, weighing 7.0625 pounds. I found that nearly all the copper cylinders measured within less than $\frac{1}{1000}$ of an inch of .499" in length, whereas Capt. Rockwell gives .502" as their length. This difference was doubtless due to an index error in one of our calipers, but this was unimportant, as the reading of the compression would not be affected thereby.

The following table was made in this way: I dropped the weight from successive heights, beginning with one foot and going up one foot higher each time. At any point where there seemed to be any anomaly in the compression, the experiment was repeated till the doubt was settled. I then began again at 6 inches and went up one foot at a time, so as to get interpolations, anomalies being treated as before. The cylinders proved to be remarkably uniform in their resistance. They retained the cylindrical form very accurately up to a compression of about one-third of their length; beyond this they were barrel-shaped. Under the heavier impacts of the piston a decided rise in temperature was noticed when the little plug was picked up. This was of interest, as the mechanical equivalent of

heat has been determined by this method. I have taken the trouble to calculate the theoretical rise of temperature.*

I made, also, some experiments to determine whether there is any radical difference between copper and lead as registers of work. I *found that a copper cylinder, partly compressed, will record a second blow, and even a third or greater number with the same or even greater accuracy than lead.* I also proved, by changing my weight, using the 24, 12 and 2-inch pieces of shafting, that the recorded work is independent of the relation of the factors, provided their product is constant—that is, a piston 8″ long dropped 2 feet is equal in effect on the copper cylinder to a 2-inch dropped 8 feet. I also proved that the *copper is sensitive enough to record a very small work, even when already highly compressed.*

If we compare the following table with the data already compiled for lead plugs, we will find that the curve for the copper cylinders falls between the curves for the .75-inch and 1-inch (soft) lead plugs, being nearer the latter; that is, a copper cylinder .25 inches in diameter and .50 inches long gives *about* the same curve as a lead cylinder .93 inches in diameter and 1 inch long. As the sectional areas of the copper and this lead are as 1 to 14, if we take into account the average effect of the difference in length which we can estimate from our general equation, $x = \frac{KALy^a}{L-y}$, which effect increases with the compression, we can say roughly that the ratio of the *sensitiveness* of the two materials to *dynamite* compression is 1 to 10; that is, copper requires ten times as much work as lead to produce equal compressions.

* The calculation of the rise in temperature is made for a fall of 10 feet, giving 70.625 foot-pounds = .09148 British heat units, calling a Joule 772 foot-pounds. The specific heat of copper being .0930, this would raise .9836 pounds (not quite one pound) of copper one degree Fahrenheit. The average weight of the copper cylinders is 3.552 grammes. The number to the pound is 127.7, the number to .9836 pounds is 125.8, which is the number of degrees Fahrenheit this work would raise the temperature of the cylinder. If the primitive temperature were 60°, this would make the temperature of the copper 185°.8, provided, of course, there was no loss. If the crushing were done on a non-conducting surface, the plug would be hot enough to burn the fingers.

The same amount of work would not raise the temperature of the one-inch lead plugs noticeably. Taking their average weight at 145 grammes (40.82 times the copper), the specific heat of lead being .0315, the rise in temperature would be

$$125°.8 \times \frac{2.952}{40.82} = 9°.09 \text{ Fahr.}$$

TABLE NO. 1.

First Set Experiments, Copper Cylinders Crushed by Falling Weight. Weight, 2" Steel Shafting, 8" long, Weighing 7.0625 Pounds. Copper Cylinders, .25" diameter, .499" long.

Drop in feet.	Work, foot-pounds (x).	Reduced length of cylinder in $\frac{1}{1000}$ inch.	Compression (y) in $\frac{1}{1000}$ inch.	Mean resistance, $\frac{x}{y}$
0.5	3.531	465	34	.104
1	7.0625	443	56	.126
1.5	10.594	427.5	71.5	.148
2	14.125	412	87	.162
2.5	17.66	400	99	.178
3	21.187	389	110	.192
3.5	24.72	378	121	.204
4	28.25	367	132	.214
4.5	31.78	357	142	.224
5	35.31	349	150	.235
5.5	38.84	338.5	160.5	.242
6	42.37	331	168	.252
6.5	45.91	323	176	.261
7	49.44	314	185	.267
7.5	52.97	306	193	.274
8	56.50	299	200	.282
8.5	60.03	292	207	.290
9	63.56	285	214	.297
9.5	67.09	280	219	.306
10	70.62	273	226	.312
10.5	74.16	268	231	.321

In this table thousandths of an inch have been treated as whole numbers. It will be noticed that the mean resistance increases pretty regularly with the compression. The curve corresponding to this table will be found plotted on a small scale on Plate III (see Fig. 1). In order to deduce an equation for the curve, I have taken from the latter the following list of new co-ordinates:

$y = 25$	$x = 2.4$
$y = 50$	$x = 6.4$
$y = 75$	$x = 11.7$
$y = 100$	$x = 18$
$y = 125$	$x = 25.8$
$y = 150$	$x = 35.3$
$y = 175$	$x = 45.5$
$y = 200$	$x = 57$
$y = 225$	$x = 70$

These figures have no pretence to minute accuracy, the scale used for the curve being small.

Assuming the equation used for lead plugs,

$$x = \frac{By^a}{499 - y},$$

we calculate the values of B and a by taking the above co-ordinates in sets of two, and find that the curve can be represented pretty accurately by the following simple equation:

$$x = \frac{18y^{1.3}}{499 - y}.$$

The following list of co-ordinates has been calculated from it:

$y = 25$	$x = 2.5$
$y = 50$	$x = 6.5$
$y = 75$	$x = 11.6$
$y = 100$	$x = 18$
$y = 125$	$x = 25.6$
$y = 150$	$x = 35.5$
$y = 175$	$x = 45.8$
$y = 200$	$x = 59$
$y = 225$	$x = 74.8$

The curve represented by the equation is given in Plate III (see Fig. 1). When applied to the first curve the agreement up to a compression of 175 is very close; beyond this the new curve inclines to the right, but for our present purpose this is immaterial.

Now we will attempt to calculate the maximum resistance corresponding to different compressions, the quantity aimed at in gun experiments. For the range of such experiments the relation between *work* and compression *seems* to be quite accurately represented by the equation

$$x = \frac{18y^{1.3}}{499 - y}.$$

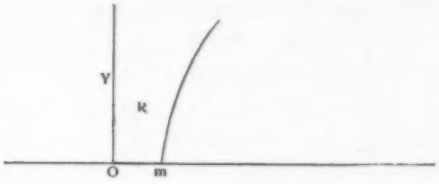
Differentiating this, we have

$$\frac{dx}{dy} = \frac{18 \times 1.3\,(499 - y)\,y^{.3} + 18y^{1.3}}{(499 - y)^2},$$

an expression for the tangent of the angle, which this curve makes with the axis of Y.

This curve gives the relation between the work (x), and compression (y).

If we now suppose the curve expressing the relation between the compression (y) and the *resistance* (R) to be constructed, and the initial resistance Om to be equal to R',



then the work x will be the area included between the curve and the axis of Y.

Let us assume

$$R = \frac{dx}{dy} = \frac{18 \times 1.3\,(499 - y)\,y^2 + 18y^{1.3}}{(499 - y)^2}.$$

Then since $x = \int R dy$, we have

$$x = \int \left(\frac{18 \times 1.3\,(499 - y)\,y^2 + 18y^{1.3}}{(499 - y)^2} \right) dy\,;$$

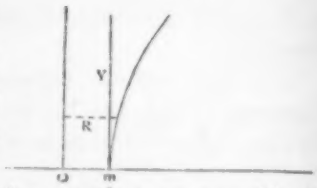
whence $$x = \frac{18y^{1.3}}{499 - y} + C,$$

which we know to be correct, since the constant C is zero.

But R cannot be equal to $\frac{dx}{dy} = \frac{18 \times 1.3(499 - y)y^2 + 18y^{1.3}}{(499 - y)^2}$ because this quantity is equal to zero when $y = 0$, whereas R by hypothesis is equal to R'; so we conclude that the form of our equation $\left(x = \frac{By^2}{L - y} \right)$ is defective for our present purpose. The defect of this form of equation is that it gives a curve *tangent* to the axis of Y at the origin, whereas the curve should make an angle with this axis at the origin, the tangent of which is equal to the initial resistance.

If we consider the work due to the initial resistance and the path separately from the work due to resistances developed by com-

pression and increase of area, and call the latter z, we have $x = z + R'y$, in which z will represent the area included between the R, y curve and a new axis of Y drawn through the point m.



We can determine the values z from the equation $z = x - R'y$, if we know the values R' and x. We can get the values of R' *approximately*, if we have a suitable table of values of x, by determining x when $y = 1$. If we suppose the R, y curve to be a straight line between the origin and this small value of y, then this value of x will be the resistance for $y = \frac{1}{2}$. Moreover, if we can express the value of z by an equation of the form $z = \frac{By^2}{L - y}$, the z, y curve will be tangent to the new axis of Y at the origin, and R for $y = \frac{1}{2}$ will be practically equal to R for $y = 0$, or R'.

The first step was, therefore, to construct a new table of small values for x. For this purpose I prepared a small foot-pounds machine and used as my weight the 2-inch piston, weighing 1.766 pounds. To insure greater accuracy in measuring the cylinders, both before and after compression, I attempted to divide the $\frac{1}{1000}$ of an inch. In the following table I give the original experiments except a few rejected as failures.

TABLE NO. 2.

Second Set Experiments with Falling Weight (Foot-pounds Machine) on Copper Cylinders. Weight 2" long, 1.766 pounds.

Drop in inches.	Work, foot-pounds (x).	Original length of cylinder ($\frac{1}{1000}$ inches).	Reduced length of cylinder ($\frac{1}{1000}$ inches).	Compression in ($\frac{1}{1000}$ inches).	Average compression ($\frac{1}{1000}$ inches).	Mean R. $\frac{x}{y}$
¼	.0368	499.3	499	.3	.3	.123
¼	.0368	499.7	499.4	.3		
½	.0736	499.4	498.5	.9	1.17	.063
½	.0736	499.5	498	1.5		
½	.0736	499.6	498.2	1.2		
½	.0736	499.6	498.3	1.3		
½	.0736	499.6	498.6	1.		
½	.0736	499.5	498.4	1.1		

Drop in inches.	Work, foot-pounds (x).	Original length of cylinder ($\frac{1}{1000}$ inches).	Reduced length of cylinder ($\frac{1}{1000}$ inches).	Compression in ($\frac{1}{1000}$ inches)	Average compression ($\frac{1}{1000}$ inches.)	Mean R. $\frac{x}{y}$
¾	.1104	499.7	498	1.7		
¾	.1104	499.6	498.2	1.4	1.57	.070
¾	.1104	499.7	498.1	1.6		
1	.147	499.5	497.6	1.9		
1	.147	499.5	497.4	2.1		
1	.147	499.6	497.6	2.0	2.025	.072
1	.147	499.3	497.2	2.1		
2	.294	499.3	494.6	4.7		
2	.294	499.6	495	4.6	4.57	.064
2	.294	499.4	495	4.4		
3	.442	499.2	492.5	6.7		
3	.442	500.1	492.8	7.3	6.6	.067
3	.442	499.2	493	6.2		
3	.442	499.4	493.2	6.2		
4	.589	499.2	490.6	8.6		
4	.589	499	490	9.0	9.1	.065
4	.589	500	490.5	9.5		
4	.589	499.3	490	9.3		
5	.736	499.2	488	11.2	10.95	.067
5	.736	499.	488.3	10.7		
7	1.030	499.5	485.5	14	14.	.074
9	1.324	499.3	481.4	17.9	17.9	.075
12	1.766	499.	476.9	22.1	22.1	.080
15	2.207	499.6	474	25.6	25.6	.086
18	2.659	499	470	29	29.	.092
24	3.532	499	464.5	34.5	34.5	1.02

This table cannot be regarded as a complete success; according to the theory which we have adopted the mean resistance should be nearly constant for very small compressions and then increase slowly, whereas it begins with a value .123 and then drops to .063. Some importance is to be attached to this latter value as it was the mean result of six experiments. A law of increase in the mean resistance is noticed, beginning at the 2 inch drops; with some irregularities, it is true, and probably from this point the table is fairly reliable. If we had to decide the question from this table, we would

say that the initial resistance is approximately .063. For the present we reject the data below 2 inches.

For the higher compressions the apparatus worked well, and the accepted data may be regarded as a supplement to the table determined before with the 8-inch piston, with which it connects very well. My next move was to construct a more delicate apparatus—a miniature foot-pounds machine in which the weight was a polished steel cylinder ⅝ inch in diameter and 3 inches long. The anvil consisted of a steel rod of the same diameter, 15 inches long. The results with this apparatus are given in the following table. I expected great things from it and was proportionately disappointed, as will be seen in due course.

TABLE NO. 3.

Third Set of Experiments with Foot-pounds Machine and Copper Cylinders. Weight ⅝" x 3", .259 pounds.

Fall in inches.	Work, foot-pounds (x).	Original length of cylinder ($\frac{1}{1000}$ inches).	Reduced length of cylinder ($\frac{1}{1000}$ inches).	Compression (y) ($\frac{1}{1000}$ inches).	Average compression ($\frac{1}{1000}$ inches).	Mean R. $\frac{x}{y}$
½	.01079	499.9	499.8	.1	.1	.108
¾	.01618	499.6	499.5	.1	.1	.162
1	.02158	499.5	499.3	.2	.2	.108
1	.02158	499.6	499.4	.2		
1½	.03237	499.6	499.4	.2	.2	.162
1½	.03237	499.7	499.5	.2		
1½	.03237	499.6	499.6	0.0		rejected
1¾	.03776	499.7	499.4	.3	.3	.126
1¾	.03776	499.7	499.4	.3		
2	.04316	499.8	499.4	.4	.4	.108
2½	.05395	499.5	499	.5	.5	.108
3	.06475	499	498.4	.6	.65	.100
3	.06475	499.7	499	.7		
3½	.07553	499.6	498.7	.9	.95	.079
3½	.07553	499.6	498.6	1.0		
4	.0863	499.2	498.1	1.1	1.1	.078
5	.1079	499.4	498	1.4	1.4	.077
5	.1079	499.5	498.1	1.4		
6	.1295	499.5	497.8	1.7	1.7	.076

Fall in inches.	Work, foot. pounds (x).	Original length of cylinder ($\frac{1}{1000}$ inches).	Reduced length of cylinder ($\frac{1}{1000}$ inches).	Compression (y) ($\frac{1}{1000}$ inches).	Average compression ($\frac{1}{1000}$ inches).	Mean R. $\frac{x}{y}$
7	.1511	499.5	497.5	2.0	2.0	.075
9	.1942	499.6	497	2.6	2.6	.075
12	.259	499.4	495.7	3.7	3.6	.072
12	.259	499.5	496.	3.5		
14	.3022	499.8	495.5	4.3	4.2	.072
14	.3022	499.2	495.1	4.1		
16	.3453	499.6	494.8	4.8	4.8	.072
18	.3885	499.2	493.9	5.3	5.3	.073
21	.4532	499	492.8	6.2	6.2	.073
24	.518	499.4	492.3	7.1	7.1	.073
28	.604	499.3	491	8.3	8.4	.072
28	.604	499.5	491	8.5		
31	.669	499.5	490.5	9.0	9.2	.073
31	.669	499.7	490.3	9.4		
35	.755	499.2	489 3	9.9	10.0	.075
35	.755	499.5	489.4	10.1		
38	.8202	499.6	488.9	10.7	10 65	.077
38	.8202	496.6	489	10.6		

In examining this table we are struck with the irregularity of the mean resistance for the smaller drops. This was to be expected, to a certain extent, as the compression below $\frac{1}{1000}$ is, more or less, guessed at. It is curious, however, that the mean resistance should be so large for very small values of x, an anomaly noticed before, to a slight extent, with the 2-inch piston. Below 3½ inches fall the table is valueless. This table should connect with the previous one, but we find that it does not.

In the previous table a compression of 9.2 corresponds to .604 foot-pounds. In this table it corresponds to .669 foot-pounds. The reason, however, is not far to seek. With this light piston there was a decided *rebound*. In some cases the rebound was sufficient to allow the copper cylinder to turn over on its side. This trouble was experienced very slightly with the 2″ piston, but was neglected as unimportant. It the present case it vitiated the whole work. The rebound was not uniform. It was decidedly greater on some plugs than on others, when the falls were equal. *It was greater for small*

falls than for large, but could be noticed up to the last. I roughly estimated at about 30 inches fall that the upward rebound was ¼ inch. At 1½ inches it was nearer ⅜ inch. Now what did this rebound mean? Did it mean that the compression was within the elastic limit of the copper and that part of the compression was restored? On this point one experiment is instructive. One of the 1½ falls gave a remarkably high rebound, fully half an inch, and the copper cylinder turned over on its side. The compression was found to be *nil.* To test the cylinders for elasticity I dropped them endwise from varying heights up to about 15 inches upon a steel plate. They rebounded more or less. The greatest height of rebound was estimated at ⅜ inch. The *miniature foot-pounds apparatus developed individual differences in the copper cylinders, the presence of which was unsuspected.* These irregularities were probably due to the effect of the tool used to turn off the ends. It is necessary to say, however, that these differences would have been insignificant in ordinary work.

The effect of the rebound was to increase the apparent mean resistance, and the results of the table agree with observation. The rebound was greatest for small drops, likewise the values of the mean resistance given in the table. General Abbot, in his experiments with the pendulum hammer on lead plugs, observed a rebound, and corrected the fall by deducting the fall due to the rebound or recoil. I have no doubt he proved this correction sufficient. In the present case, even if I had been able to estimate the height of rebound accurately, it would not have been a sufficient correction. The error is too large. Assuming the data obtained with the 2″ piston to be correct, the error averages about $\frac{1}{7}$ of the fall. A very slight rebound was observed at very small heights with the 2″ piston. It remained to determine whether the irregularities of this table (page 550) were due to this cause. If by using a heavier piston the average mean resistance were reduced, it would show that the 2″ piston was also unreliable.

For this test I selected a piston 4 inches long, having exactly twice the weight of the 2″.

TABLE NO. 4.

Fourth Set of Experiments, with Foot-pounds Machine and Copper Cylinders. Weight 4" long, 3.532 pounds.

Fall in inches.	Equivalent fall for 2" weight (inches).	Work, foot-pounds (x).	Original length of cylinder ($\frac{1}{1000}$ inches).	Reduced length of cylinder ($\frac{1}{1000}$ inches).	Compression (y) ($\frac{1}{1000}$ inches).	Mean R, $\frac{x}{y}$	Mean R for 2" weight.
¼	½	.0736	499.3	498.1	1.2	.064	.063
¼	½	.0736	499.4	498.3	1.1		
½	1	.147	499	496.7	2.3	.064	.072
1	2	.294	499.4	495	4.4	.067	.064
2	4	.589	499.1	490	9.1	.065	.065
2½	5	.736	499.1	488.6	10.5	.069	.067
3½	7	1.030	499.2	485	14.2	.072	.074
4½	9	1.324	499.7	482	17.7	.075	.075
6	12	1.766	499.5	478	21.5	.082	.080

In the last two columns I have compared the mean resistance with that of the former table for the 2" piston. It will be seen that there is a substantial agreement, *one table serving to correct the anomalies of the other*. The data of this last table is scanty, but this could not be helped as my supply of cylinders was exhausted. This was regrettable as the apparatus worked very well. No rebound could be detected.

In regard to assuming a figure for the initial resistance the best we can do is to accept .062, which is certainly a very close approximation.

By combining the results of tables Nos. 1, 2 and 4 and constructing a curve on any convenient scale, we can easily get rid of the slight anomalies present. My plan for doing this is to plot all the points given by the tables and prick these on a thin board. With a sharp knife I cut the edge of the board to a curve passing as nearly as possible through these points, and finish the curve with a very small plane and emery cloth. Points which are too prominent are cut away, those which are reëntrant are left inside of the curve. The wooden template, when finished, is used to draw a new curve from which new co-ordinates may be taken. The results of this work are given in the following table.

It was my original intention to obtain the values of R by first getting a table of values of z from the expression $x = .062y + z$ and

then deducing an equation for the z, y curve of the form

$$z = \frac{By^a}{499 - y};$$

R would then be equal to $.062 + \frac{dz}{dy} = \frac{dx}{dy}$.

But it was essential that the equation $z = \frac{By^a}{499 - y}$ should be reliable for both very small and large values of y. I found great difficulty in fulfilling these exacting conditions, and concluded to abandon the method. My results would have been inaccurate at best.

I obtained the values of R, corresponding to different ordinates, by constructing tangents to the x, y curve at the extremities of the ordinates, and determining the tangent of the angle which these tangents made with the axis of Y—a practical determination of $\frac{dx'}{dy'}$. The x, y curve for the purpose was drawn on a large scale. I then constructed an R, y curve from the values of R found, and got rid of anomalies as usual. The x, y curve and R, y curve will be found on a reduced scale on Plate III, Fig. 2. (The x, y curve is substantially the same as in Fig. 1.) I have roughly checked the values of R given in the table in several ways. In the first place, it is evident that in a curve of the form of the x, y the tangent of the angle corresponding to a given ordinate as y', will be greater than the difference between the values of x for $y' - 1$ and y', and will be less than the difference between the values of x for y' and $y' + 1$. This follows, since the curve continually increases its curvature from the axis of Y.

I give a series of these differences in the values of x in the table for comparison with the values of R.

Secondly, we have a check in the equation

$$x = \frac{18y^{1.3}}{499 - y},$$

from which we have

$$R = \frac{dx}{dy} = \frac{18 \times 1.3\,(499 - y)\,y^{.3} + 18y^{1.3}}{(499 - y)^2},$$

which is quite accurate below $y = 200$, except for very small values of y.

Lastly, I have made a practical integration on section paper of the area between the R, y curve and the axis of x for various ordinates, and compared this area with the corresponding value of x, and

found in every case a substantial agreement. I therefore believe the values of R to be approximately correct.

Table showing Relation between the Work, Compression and Resistance of Copper Cylinders (25 × .50), *crushed by a Falling Weight.*

y = compression expressed in thousandths of an inch.
x = kinetic energy of the weight (work), expressed in foot-pounds.
R = resistance of the copper expressed in units of 12,000 pounds.

y	x	Difference in value of x for 1 y.	R	Mean R. $\frac{x}{y}$
0	.0		.062	.0
		.063		
1	.063		.064	.063
		.065		
2	.128		.065	.064
		.066		
3	.194		.066	.065
		.068		
5	.330		.070	.066
		.074		
10	.700		.078	.070
		.080		
15	1.10		.090	.073
		.094		
20	1.57		.102	.078
		.112		
25	2.13		.118	.085
		.134		
30	2.80		.135	.093
		.154		
40	4.34		.156	.108
		.171		
50	6.05		.178	.121
		.193		
60	7.98		.200	.133
		.212		
70	10.10		.222	.144
		.232		
80	12.42		.245	.155
		.258		
90	15.00		.268	.167
		.285		
100	17.85		.290	.178
		.308		
110	20.93		.311	.190
		.331		
120	24.24		.329	.202
		.346		
130	27.70		.348	.213
		.358		
140	31.28		.365	.223
		.372		
150	35.00		.382	.233
		.390		
160	38.90		.401	.243
		.410		
170	43.00		.422	.253
		.430		
180	47.30		.444	.263
		.450		
190	51.80		.467	.273
		.473		
200	56.53		.501	.283
		.512		
210	61.65		.538	.294
		.560		
220	67.25		.577	.305
		.617		
230	73.42		.620	.319

It only remains to convert the resistances into pounds. Our values of x, numerically equal to the foot-pounds, are really made up of very different units. A unit of work consists of two factors, one representing force—a weight or pressure—the other a path or distance. A foot-pound is equal to twelve pound-inches or twelve-thousandth of an inch. In the present case, the unit of the path being $\frac{1}{1000}$ of an inch, the unit of intensity is 12,000 pounds, the quantity by which it is necessary to multiply the values of R to convert them into pounds. The value of R thus obtained represents the intensity of the force in pounds necessary to produce the corresponding compression of the cylinder (see Table 5, below). Two values are given: one, the mean value, supposes the resistance constant throughout the path; the other is intended to be an actual measure of the intensity of the force or the resistance at the instant of maximum compression.

Comparison of Dynamic Resistances and Rodman Pressures.

To get a comparison of my resistances with the pressures obtained with the Rodman testing machine, I wrote to Captain Rockwell for a more complete table. He sent me a table made by himself, ranging from a compression of .21 to .228; also a very complete table made at Frankford Arsenal, in 1890, for the same cylinders, ranging from a compression of .44 to .260. The agreement between the two is very close, showing that the indications of the testing machine are reasonably positive. The Frankford table is given below. In the original the reduced length of the cylinder only is given. To get the compressions I have assumed the original length to be exactly 500. In the original table the pressure given is "on the square inch." As the piston used had a sectional area of $\frac{1}{10}$ inch, I have divided these numbers by 10 to get the pressure on the cylinder. Following is the table in condensed form.

TABLE OF PRESSURES ON COPPER CYLINDERS.

Rodman Testing Machine, Frankford Arsenal, 1890. *Original Table Abridged.*

Reduced length of cylinder ($\frac{1}{1000}$ inches).	Compression ($\frac{1}{1000}$ inches).	Pressure (pounds).
456.4	43.6	1500
451.9	48.1	1600
447.2	52.8	1700
442.3	57.7	1800
438.4	61.6	1880
434.1	65.9	1960
430.2	69.8	2040
426.0	74.0	2120
421.9	78.1	2200
417.6	82.4	2280
413.3	86.7	2360
404.6	95.4	2520
400.2	99.8	2600
389.1	110.9	2800
378.2	121.8	3000
366.8	133.2	3200
356.0	144.0	3400
344.9	155.1	3600
334.1	165.9	3800
323.5	176.5	4000
298.6	201.4	4500
276.8	223.2	5000
257.4	242.6	5500
241.0	259.0	6000

To obtain the interpolations needed for direct comparison with my resistances, I plotted the foregoing data on a large scale and obtained a remarkably regular curve which bears a marked general resemblance to my R, y curve (see Plate III, Fig. 3, in which both are given on a reduced scale). I took the required data from this curve, and it will be found in the last column of the following table, which is a summary of my work on copper cylinders in the foot-pounds machine. (The "dynamic pressure" curve in Fig. 3, Plate III, is the same as the "resistance" or R, y curve in Fig. 2, the abscissas being distorted by the use of a different scale in the two figures.)

TABLE NO. 5.

Table Showing Work, Compression, and Resistance of Copper Cylinders Compressed by a Falling Weight; also Rodman Pessures.

Compression (y) ($\frac{1}{1000}$ inches).	Work (x) (foot-pounds).	Resistance, final intensity of force (R) (pounds).	Mean resistance $\left(\frac{x}{y}\right)$ (in foot-pounds).	Rodman pressures (Frankford) (P) (pounds).		Ratio $\left(\frac{R}{P}\right)$
1	.063	768	756	510	hypothetical, taken from curve.	1.5
2	.128	780	768	.....		.....
3	.194	792	776	.....		.....
5	.330	840	792	.....		.....
10	.700	936	840	720	hypothetical,	1.3
15	1.10	1080	880	840	from the curve.	1.3
20	1.57	1224	942	955	Rockwell.	1.3
25	2.13	1416	1022	1070	"	1.3
30	2.80	1620	1120	1200	"	1.3
40	4.34	1872	1302	1410	Frankford.	1.3
50	6.05	2136	1452	1630		1.3
60	7.98	2400	1596	1845		1.3
70	10.10	2664	1731	2045		1.3
80	12.42	2940	1863	2240		1.3
90	15.00	3216	2000	2420		1.3
100	17.85	3480	2142	2605		1.3
110	20.93	3732	2283	2795		1.3
120	24.24	3948	2424	2975		1.3
130	27.70	4176	2557	3145		1.3
140	31.28	4380	2681	3325		1.3
150	35.00	4584	2800	3505		1.3
160	38.90	4812	2919	3690		1.3
170	43.00	5064	3035	3870		1.3
180	47.30	5328	3153	4060		1.3
190	51.80	5604	3272	4265		1.3
200	56.53	6012	3391	4460		1.3
210	61.65	6456	3523	4660		1.4
220	67.25	6924	3668	4875		1.4
230	73.42	7440	3831	5110		1.4

In the above table the "Rodman pressures" (5th column) below a compression of 20 are hypothetical—obtained by prolonging the

curve. Between 20 and 40 they are from Captain Rockwell's data. Comparing the "resistances" with "pressures," there is no close agreement, but a constant ratio of 1.3 between the two, except near the two extremes of the table, and there the ratio is either 1.4 or 1.5 (compare curves on Plate III, Fig. 3). This result, when it is considered by what very different methods the two series of numbers were obtained, is certainly remarkable.

Low and High Forms of Copper Resistance.

It appears from this that the resistances developed in the falling weight machine are uniformly about 1.3 times the pressures as determined slowly in the Rodman testing machine. Both are intended to measure the intensity of the force which is in equilibrio with the copper resistance corresponding to a given compression. Which is right? Probably both; that is, the resistance of the copper varies with the circumstances of the compression. It offers greater resistance when the compression is hurried, and less when the compression is slow. In this respect, therefore, copper resembles lead. The difference between them is one of degree only, as we predicated upon *à priori* principles. In lead we have seen that the property is so marked that a practicable scale cannot be made with the testing machine. To support our reasoning we bring to our aid the authority of Prof. R. H. Thurston, one of the members of the celebrated U. S. Board for testing metals, which a few years ago discovered and formulated the *law of the elevation of the limit of stress of iron*. Prof. Thurston found that copper, tin and lead formed a class of metals opposite in their qualities to iron. They have no elevation of the limit of stress, but oppose increased resistance to sudden strains and a lessened resistance to slow strains.

The only other investigator in this special field is General Abbot. He made a comparison of pressure and shock upon copper discs, using Rodman's indenting piston—not the curved, but the angular or pointed cutter, the angle being 163°30′ made by the two parts of the wedge. He concluded that the Rodman pressures should be taken to represent *mean*, not *maximum* pressures. By subjecting the discs and piston to the action of his pendulum, and dividing the kinetic energy or (work in foot-pounds) by the indentations (depths of cut expressed in feet), he obtained numbers which compared well with the pressures of the Rodman tables. On page 28 of his Report he gives a table of his results. In regard to this he

says: "The last two columns show a surprising correspondence between scales of absolute pressure obtained by methods so radically different as those of Rodman and my own. . . . The comparison of the two methods certainly tends to confirm the practical value of the Rodman scale, except, perhaps, for low pressures."

General Abbot's work certainly proves that for the double wedge cutter, or indenting tool, the Rodman pressures are practically equal to the *mean* resistances developed by a blow. This is an interesting and surprising result. In the compression of the cylinders we have seen that the Rodman pressures are directly proportional to the *maximum resistances* developed by a blow and bear no simple relation to the mean resistances. I have thought it worth while to make a comparison between the maximum resistances and the Rodman pressures for the double wedge cutter also.

Comparison of Dynamic Resistances and Rodman Pressures for the Pointed Cutter Piston or Indenting Tool.

For this purpose I use the data of General Abbot's table. I first plot a curve on a large scale using the work (W) expressed in foot-pounds as abscissas, and the computed indentations (I) expressed in $\frac{1}{1000}$ of a foot as ordinates. I then construct tangents to the curve at the extremities of the ordinates, and determine the tangents of the angles which these make with the axis of Y. These values of the tangents, multiplied by 1000, are the maximum resistances (or the resistances corresponding to the tabular indentations) expressed in pounds. As the accuracy of the results is a question of construction, I check the values of $\frac{R}{1000}$ thus obtained by plotting a new curve (R, I curve), using these values as the abscissas and the indentations as ordinates. From this new curve I take my final values of $\frac{R}{1000}$. I have checked these by practical integration of the R, I curve, as well as by comparison with successive differences in the value of the work. I therefore believe my results fairly accurate. Luckily, in this case, I can check them absolutely, though I must frankly admit thas this was an after thought. During the course of my work I noticed with interest that the W, I curve was evidently tangent to the axis of Y at the origin; also, that the the R, I curve passed through the origin. That is, the initial resistance is zero, which is reasonable, in view of the sharp point on the cutter. I

then began to cast around for an equation for the W, I curve, when I found it staring me in the face, General Abbot having already deduced it; in fact, he uses it to compute the indentations.

The equation is $I = .002156 W^{\frac{1}{3}}$, whence $W = \frac{I^3}{.002156^3}$, in which W is the work in foot-pounds, and I is the path or indentation in feet.

If we let R equal the resistance in pounds,

we have $$W = \int R dI.$$

Differentiating, we have $$R = \frac{dW}{dI},$$

and applying this to the equation above,

$$R = \frac{3I^2}{.002156^3}.$$

From this, by substituting for I the tabular indentations, we can deduce the absolute values of the corresponding resistances.

I have concluded to let my values deduced by the graphic method appear in the table also, though the only purpose they serve is to show what accuracy can be expected by an unskilled draughtsman in using this method.

RODMAN TESTING MACHINE AND PENDULUM HAMMER.

Comparison of Pressure and Shock on Copper (Indenting Tool).

Kinetic energy of pendulum (W) work.	Copper indentations computed (I).	Rodman pressures (P).	Mean resistance $\left(\frac{W}{I}\right)$.	Max. resistance (R), graphic methods.	Max. resistance, $R = \frac{dW}{dI}$.	Ratio $\left(\frac{R}{P}\right)$
Foot-pounds.	Feet.	Pounds.	Pounds.	Pounds.	Pounds.	
0.226	.00131	285	172	490	514	1.8
0.630	.00184	533	340	970	1,013	1.9
2.496	.00292	1,180	855	2,550	2,552	2.16
5.532	.00380	1,880	1,451	4,350	4,323	2.3
9.743	.00460	2,584	2,116	6,200	6,334	2.45
14.860	.00530	3,315	2,803	8,200	8,409	2.54
21.290	.00597	4,040	3,566	10,300	10,669	2.64
28.930	.00662	4,867	4,371	12,950	13,119	2.69
37.370	.00721	5,660	5,186	15,500	15,561	2.75
46.800	.00777	6,463	6,025	18,000	18,072	2.79
57.000	.00830	7,280	6,872	20,600	20,622	2.83
67.980	.00880	8,110	7,725	23,500	23,181	2.86
79.610	.00927	8,890	8,590	26,300	25,724	2.89

The first four columns of the above table are taken from General Abbot. The other three columns are mine. The last column gives the ratio $\left(\frac{R}{P}\right)$ of the maximum dynamic resistances to the Rodman pressures. It will be noticed that this ratio is not constant, as in the case of the copper cylinders, but increases for the limits of the table from about 1.8 to 2.9 (see curves, Fig. 4, Plate III).

The table shows that General Abbot's point in regard to a substantial equality between the Rodman pressures and the *mean resistances* $\left(\frac{W}{I}\right)$ is well taken. We must regard this in the light of a coincidence which results from the form of the cutter. If we interpret these results by the light which we have already obtained on the subject, it appears that the resistance R developed by a blow is greater than the resistance P developed by pressure, and that the ratio $\left(\frac{R}{P}\right)$ between these quantities increases with the indentation. This results from the form of the cutter. The initial resistance is zero for both applications of force, so that this ratio must begin as an equality, or 1, and increase to its limiting value, which appears to be beyond the confines of the table.

In the cylinders, on the contrary, there is a well-defined initial resistance for both applications of force, and the ratio $\left(\frac{R}{P}\right)$ may and does hold a constant value from the beginning.

The form of indenting tool or Rodman cutter, now generally used, has a curved edge, usually the arc of a circle. I have no data at hand to determine its properties under the action of a blow or falling weight, but think it will develop a very small initial resistance. Otherwise its action will closely resemble that of the cutter used by General Abbot.

Application to Explosives.

It will be noticed that we have been careful so far to say as little about the intensity of the acting force as possible. We will now explain why.

From the standpoint of the artillerist, a given compression or indentation indicates that a certain pressure has been exerted, or a force has acted with a certain intensity. Having regard to the

whole field of explosives, we prefer to say that a certain amount of work has been done. A force has acted in producing this work, and the *final* intensity of this force is represented by the artillerist's pressure, or by our resistance, depending upon whether the force has acted slowly or quickly. In either case final intensity is the only intensity measured.

Case of Falling Weight or Impulsive Force.

The case of a disc indented or cylinder compressed by a blow or falling weight has some features of its own, and differs from the general case of work by an explosive; nevertheless, as it has been used to prepare our tables, we may get some light by discussing it.

What is the intensity of the force in this case? Evidently the measure we aim at is the intensity of the force at the moment of contact. This is strictly analogous to an explosive which delivers its blow in one impulse; but, as no explosive acts in this way, though the fulminates may proximate it, we see that we are dealing with a special problem. In the practical case of using the gauges to determine *the action of an explosive*, the record enables us to determine the *final* resistance of the copper only, which is equal to the final intensity of the force.

We know nothing of the intermediate history of the force from the beginning of its action to its close, except that its intensity at any intermediate point must have exceeded the corresponding copper resistance in order to overcome it. The law of variation in the intensity of the force during the time of action, so far as the record of the work discloses it, is a sealed book.

The work relates only to the *resistance* and the *path*. The intensity of the force may have been greater in the beginning, and diminished to an equality with the resistance which limited the path; it may have been constant throughout; or it may have increased during the period of action, but less rapidly than the resistance. The record on the copper furnishes us no data for determining the nature of the change. It gives the intensity at one point only, and even this must be obtained by an intelligent interpretation of the record.

In regard to the *mean intensity*, this, to my mind, is a conventional quantity that has no application as a measure of the force in

this case. To use it as such is to assume that the force is in equilibrio with the resistance at every point, and that its intensity is an average of the resistances; but we know that the intensity of the force must be greater than the resistance at every point except one, at which it is just equal to it. Mean intensity obtained by dividing the work by the path is, therefore, misleading, and bears no necessary relation to the force.

Returning to consider our special case, that of a falling weight, what is the intensity of the force corresponding to a given record? The measure we desire is the maximum intensity which coincides with the beginning of the action.

We know that the kinetic energy or work is equal to $\frac{1}{2}\frac{WV^2}{g} = Wh$, in which W is the weight of the falling body, V its velocity at the moment of impact, h the height of fall, and g the velocity impressed by the force of gravity in the unit of time. This energy is transferred to the piston or cutter, which is thus animated with a velocity that will cause it to describe a path shorter or longer, depending upon the resistance encountered.

The intensity of the force will diminish during the description of the path, and the path will end when the resistance encountered is equal to the diminished intensity of the force.

To throw further light on the subject I have prepared a new table comparing the final intensities of the force in the two cases of the indented discs and compressed cylinders for the *same work*. This table has been compiled from previous tables by graphic interpolations. The paths (indentations or compressions) are given in feet, also the mean resistances, obtained by dividing the work by the path. (See p. 567 for table.)

This table serves to show the relation between the three quantities, work, resistance, and path, for both cylinders and discs under the action of a falling weight. We can easily see by a study of this table that the only measure of the force is the work. Final intensity, as deduced from the record, is a *term related to previous resistances and the length of the path*. To illustrate:

1 foot-pound expended in indenting the copper disc shows a final intensity for the force of 1075 pounds.

1 foot-pound, in compressing the cylinder, shows also 1075 pounds final intensity, the ratio being 1:1.

60 foot-pounds on the disc shows a final intensity of 19,850 pounds. The same energy expended on the cylinder shows only 6300 pounds, the ratio being 3:1.

Nor does the mean intensity—work divided by the path—give more consistent figures.

1 foot-pound on the disc gives a mean intensity of 476 pounds.

1 foot-pound on the cylinder gives 860 pounds, the ratio being 1:1.8.

60 foot-pounds on the disc gives 7109 pounds mean intensity.

60 foot-pounds on the cylinder gives 3478 pounds, the ratio being 2:1.

This shows that no reliable absolute figure for the intensity of the force can be obtained in this way, since by using a very high resistance and restricting the path the intensity can be indefinitely increased. The table, moreover, shows that no reliable *relative* figure can be obtained, for one column of resistances is just as reliable as the other, and they are inconsistent with each other.

Relation between Work, Resistance (Final Intensity), and Path. Compression and Indentation of Copper by a Falling Weight. (Rodman Pointed Cutter Used for Indentation.)

Work (W) foot-pounds.	Indentation of copper discs.		Compression of copper cylinders.		Discs.	Cylind'rs	Relative intensity $\frac{\sqrt{W}}{A} \times 1000$.
	Path.	Final intensity of force.	Path.	Final intensity of force.	Mean resistance.	Mean resistance.	
	Feet.	Pounds.	Feet.	Pounds.	Pounds.	Pounds.	Pounds.
0.1	.00100	250	.000132	770	100	760	316
0.2	.00125	450	.000258	780	160	776	447
1.0	.00210	1,075	.00116	1,075	476	860	1,000
2.0	.00271	2,100	.00198	1,400	738	1,010	1,414
5.0	.00365	4,100	.0036	2,000	1,370	1,390	2,236
10.0	.00463	6,560	.0058	2,610	2,160	1,724	3,163
20.0	.00587	10,360	.0089	3,630	3,407	2,247	4,472
30.0	.00672	13,500	.0114	4,280	4,464	2,631	5,477
40.0	.00748	16,270	.0136	4,900	5,348	2,941	6,325
50.0	.00794	18,540	.0156	5,490	6,297	3,205	7,071
60.0	.00844	19,850	.0173	6,300	7,109	3,478	7,746
70.0	.00889	23,650	.0187	7,160	7,874	3,743	8,367

The use of mean resistance to measure the intensity of a force and its dependence on the path may be illustrated by two diagrams

of work, equal rectangles, of which the vertical dimensions represent intensity, and the horizontal dimensions represent path, thus:

It may be asked, Is there any way of getting a measure for the intensity of the force?

I think a *relative figure* of some value may be obtained by extracting the *square root of the work*.

The falling body, striking with a velocity V, may be taken to represent a motive force. The intensity of a motive force is measured by the product of the mass moved by the velocity generated during the time of action divided by the time, the force being supposed constant during the time of action. If this time is very short this last condition is immaterial. The motion of the falling body is arrested by the resistance of the copper in an interval of time so short that it cannot be measured.

We can get a clear idea of the intensity of the force embodied in our falling weight at the instant of impact by supposing the action reversed. After the compression or indentation has been completed, let the original form and temperature of the copper be suddenly restored, so as to reverse the circumstances of the action and generate in the falling body the velocity of V in the same short interval of time, and throw the body to the height h. The intensity of the force exerted will be measured by $\frac{MV}{t}$, in which M is the mass, V the velocity of the falling body, and t the short interval of time.

Let us suppose this interval of time to be practically the same throughout the range of the experiments; this is rendered probable by the following considerations.

If the interval of time varies it will affect the resistance of the copper and, consequently, the recorded work.

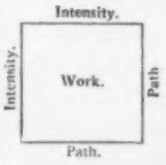
But it must be independent of the weight of the body, since we get the same record of work using different weights.

It is also independent of the height of fall, since we get the same record of work from different heights.

It follows that it is either independent of both, that is, constant, or exactly proportional to the work. But if it is proportional to the work, the formula $\frac{MV}{t}$ will give greater intensities for smaller velocities, which is absurd. The conclusion is that it is constant. Then the relative intensity will be measured by MV, and, since the mass is constant, by V, which is proportional to the square root of the work.

If this reasoning in regard to the interval of time t is unsatisfactory to the reader, then we fall back upon this simple consideration: The interval is so short that the force of restoration of the copper which will give the velocity V to the weight may be considered an *impulsive force*, the intensity of which, according to the mechanicians, is measured by MV—the quantity of motion generated during the *whole* time of action.

The use of the square root of the work to represent the intensity of the acting force is illustrated by a diagram of work, a square, in which either dimension may be considered intensity, and the other the path. In advocating the foregoing opinions, I am sorry that I do not agree on one important point with General Abbot, whose general views have had much to do with forming my own.



General Abbot regards the work registered by the gauge as the integral of the product of the force intensity into the differential of the path; consequently, he concludes that the mean pressure or intensity may be obtained by dividing the work by the path. He applies this alike to explosive mixtures and detonating compounds. It is true that he recognizes the arbitrary nature of his unit of intensity derived from copper indentations, and, moreover, shows that his final conclusions are independent of it. We also note his great need of an *absolute* unit of intensity, which he could obtain only by setting up an arbitrary test. Nevertheless, it is unfortunate that his table of intensities should be quoted as a classic by all writers on the subject, most of whom do not recognize the arbitrary nature of this unit. Perhaps it is unfair to hold General Abbot responsible for this.

While the available energy of the explosive (in the case of detonating compounds) is directly proportional to the charge, and

inversely proportional to the square of the distance (nearly), the intensity of action (mean pressure), *as a result of adopting this particular measure for it*, varies directly with the two-thirds power of the charge, and inversely with the 1.4 power of the distance.

If he had chosen to adopt the square root of the work as the relative intensity, the intensity of action would have varied as the square root of the charge, and inversely as the distance.

The point in which we differ is this: he regards force intensities as being in equilibrio with resistances. From one point of view he may be right. There are often two ways of looking at a question in mechanics; both may be right, but one may be objectionable on account of the train of consequences.

It is quite usual to speak of work as the product of the effort into the path (see Bartlett's Synthetical Mechanics, page 49), or the product of a force intensity into a path; but, strictly speaking, it is better to regard work as the product of a *resistance* and a path. The habit of regarding resistance and force intensity as equivalents is drawn, I think, from Watt's diagram of work, in which a curve limits the ordinates representing the varying pressures of a gas. The external work done by the gas is the area included between the axis of abscissas, the curve, and the extreme ordinates. But the fundamental condition is that all parts of the gas shall be at the same pressure (see Tait's Thermodynamics, page 87), which is equivalent to saying that it is in equilibrio throughout, and, consequently, in equilibrio with the resistance.

In the general case, the force intensity is not in equilibro with the resistance when performing work. To consider it so is to attach no useful meaning to the term intensity. In the case of work on the copper cylinders or discs, to consider it so gives the force its greatest intensity at the moment it ceases to work.

A weight falling from a certain height represents a certain force, the intensity of which should be a property of the force itself. But if the force be allowed to work we can get any intensity we please by this rule. By extending the path we reduce the intensity; by limiting the path we can increase it indefinitely. But, if force intensities are sometimes in equilibrio with resistances and sometimes not, where do we draw the line? It is true that forces are always in equilibrio; that is, we can find for every acting force a counterpart equal and contrary in direction. But to do this for every case, we

must sometimes consider inertia. When inertia is not considered, that is, when the motion is so slow that we may neglect it, or when the work of inertia is balanced by minus and plus work, we can safely deduce the work of the acting force from the force intensity and the path; or, reversing the operation, deduce the intensity from the work and path.

We have elsewhere said that a force intensity must always exceed a resistance to overcome it. How then, in *any case*, can the integral of the product of the force intensity into the differential of the path give the same result as the integral of the product of the resistance into the same differential?

Mechanics is filled with just such paradoxes. The difference in this case between force intensity and resistance is very slight and is not cumulative. The paradox may be illustrated by the following diagram, in which two equal triangles, almost exactly superposed, represent—one the work as deduced from the intensity, the other from the resistance.

To show what forces are in equilibrio during the compression or indentation of the copper by a falling weight, let us resume our hypothesis that, at the instant of maximum work, a force of restoration reproduces the original form and temperature of the copper, exactly reversing the circumstances of the direct action. Let us suppose the path to be divided into a number of elementary paths corresponding to a series of elementary times.

The force of restoration, now the acting force, will have an initial intensity or pressure equal to the final copper resistance in the direct action. This intensity corresponds to the first elementary time, and would, if it remained constant, generate in the body in the unit of time a quantity of motion equal to itself. The acting force will be in equilibrio with the force of inertia. During the next elementary time the force will have a slightly less intensity, which would generate in the unit of time an equal quantity of motion. The force of inertia again opposes an equal and contrary reaction, and so on, through all the elementary times.

Now let the elementary path be ds, and the elementary time dt.

The intensity of the force at any point will generate a velocity V, which may be regarded as constant during the elementary time dt,

during which the body will describe uniformly the elementary path ds. Hence we have

$$V = \frac{ds}{dt}, \text{ or } ds = Vdt; \tag{1}$$

The intensity of a motive force, or the inertia it will develop, is measured by the quantity of motion which it can generate in the unit of time, the intensity remaining constant for that time. The intensity of the force will vary, in this case becoming less and less. However, we may regard it as constant during the elementary time dt, during which it generates a velocity dV, and were it to remain constant it would generate in the unit of time a velocity $\frac{dV}{dt}$.

Denoting the varying intensity by R, we have, therefore,

$$R = \frac{MdV}{dt}, \tag{2}$$

or,

$$R = M\frac{d^2s}{dt^2},$$

that is, the intensity of the acting force, or the inertia which it develops, is equal to the product of the mass moved into the velocity impressed in the unit of time, or more simply, the mass into the *acceleration.*

Multiplying equations (1) and (2) together, we have

$$Rds = MVdV, \tag{3}$$

from which, by integration, we get

$$\int Rds = \frac{MV^2}{2}.$$

The first number is the work of the force equal to that of the inertia; the second, the kinetic energy of the body as a result of this work.

Returning to the direct case of compression or indentation by the falling body, we see that the copper resistance at every point is in equilibrio with the *successive decrements* in the quantity of motion of the body; or, what is the same thing, it is in equilibrio with the inertia developed. We now see the sense in which the force intensity and the resistance may be considered in equilibrio, the point of view which General Abbot adopts. *It is that portion of the intensity which is called into play to overcome the resistance.* The intensity

not called into play for the time being *may* be considered as pertaining to *potential* energy.

The foregoing demonstration, if it may be considered such, has not the slightest claim to originality. It is taken almost bodily from that grand old book, Bartlett's Analytical Mechanics.

Strength of Explosives.

We make a short digression to consider a subject which has engaged the attention of many practical men. *What is the proper measure of the strength of an explosive?*

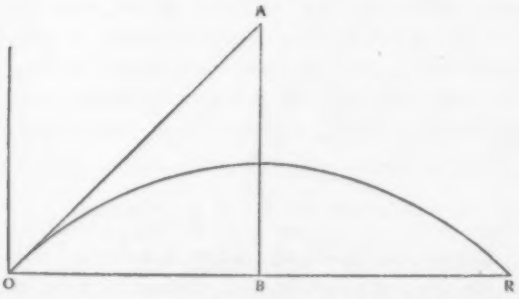
For commercial purposes there can be but one answer. Strength in this sense is a question of dollars and cents. When the miner buys dynamite he buys power; that is, something capable of doing work.

The proper measure is one which makes two pounds of the explosive twice as strong as one pound.

Let us see whether this is the compression of a lead or copper cylinder, intensity (mean or final), velocity given to a shot, or what not.

We will first consider the mortar or éprouvette, a very short gun, fixed at an angle of elevation of 45°, and throwing a heavy shot short distances, usually less than 1000 feet.

It was long ago observed that two ounces of gunpowder gave twice the range of one ounce. The rule holds with even greater exactness in the case of dynamite or other high explosive. The range is, there-



fore, the proper measure. The range being short and the shot heavy, atmospheric resistance may be neglected, and the trajectory be considered a parabola.

The height h, due to the initial velocity V, is equal to AB, but the angle of projection being 45°, OR, the range, is equal to twice AB, hence $V = \sqrt{2hg} = \sqrt{Rg}$, R being range or $V^2 = Rg$; hence the work $\frac{1}{2} MV^2 = W. \frac{1}{2} R$, in which M is the mass and W the weight of the shot. From which we see that the range is proportional to the work.

The only other measure we can consider in this case is the *intensity* of the force of projection, which is measured by the product of the mass moved into the velocity generated during the time of action divided by the time. The force is assumed to be constant during its action, and the time we can only guess at. The best we can do is to assume the intensity to be measured by the product of the shot's mass by the initial velocity, or MV, which is equal to $M\sqrt{Rg}$. This measure is based upon the velocity imparted to the shot; the other on the square of this velocity. It is needless to say that the latter measure is right and the other wrong.

To confirm our assertions we could give numerous examples of mortar experiments taken from my note books, but we trust the reader will take our word for the fact that, deducting the range due to the cap, the range of dynamite or other high explosive is very exactly proportional to the charge.

In a similar way we could show by notes of actual experiments that the work of a high explosive in the crusher gauge, as deduced from our curves, is likewise proportional to the charge. In fact, so accurate is this principle that it may be used to check a new curve or extend an old one.

We, therefore, think that the *strength of an explosive should be considered as measured by its available energy, or the work it is capable of doing under some test capable of measurement.*

In this we are not laying down any new principle, but one which has sometimes been ignored. General Abbot, however, gives it full recognition.

Application to High Explosives.

So far our discussions have been chiefly concerned with the test of explosives which are too quick in their action to have the Rodman method applied to them. We can sum up this part of our subject as follows: When the crusher or cutter gauge is used, the work and its elements, path and resistance, must be measured by a *dynamic* scale;

that is, a scale determined by the sudden application of a force. The only method so far adopted for preparing such a scale is that of the pendulum or falling weight.

This application of force develops the highest form of copper or lead resistance; consequently, a given compression or indentation will denote a greater work than the same compression or indentation by the Rodman scale, in which the low form of copper or lead resistance figures. We have shown that in crushing the copper cylinders (.25″ × .50″), by the two methods (measure and shock), these two resistances bear nearly a constant ratio of 1 : 1.3.

In the indentation of copper discs by the pointed cutter, the ratio between the low and high form of resistance increases with the path from about 1.8 to 2.9 for the limits of our data.

The ratio of these two forms of resistance, in the case of *lead*, is much larger than in copper, as shown by General Abbot; indeed lead resistance is so sensitive to change in this regard that General Abbot found it difficult, if not impossible, to establish a satisfactory Rodman scale of pressures for it.

We can say, therefore, that *lead is only suited to the dynamic scale.*

Now, keeping in mind this fact of a change in the nature of lead or copper resistance depending upon the time consumed in the application of the force, we see that the *actual* work done by an explosive may not be the same as the work or kinetic energy of the falling weight, set down in our tables as corresponding to the compression or indentation, because the explosive may be slow enough to develop a lower resistance than that encountered by the falling weight.

The error is liable to be much larger with lead than with copper, and so far as this argument goes, copper is the better of the two materials, and the cylinders better than the discs; since, in the cylinders, the extreme variation in the resistance is only from 1 to 1.3. We can usually determine from outside considerations whether the explosive is liable to excite some intermediate form of resistance.

We had in the experiments with the water crusher gauge a striking example of the effect of *prolonged action* of the explosive upon lead; but this was the result of an accident, the gauge no longer acting as such but as a mortar. In testing explosives the senstitive nature of lead resistance renders it essential that there should be an instant release of the gases, which is secured by the construction of both the

Drinker and Quinan gauges, otherwise the dynamic scale would not apply.

Practical observation in testing explosives, both with the crusher gauge and mortar, has given rise to a belief, which may be stated as a paradox, though it hardly rises to the dignity of a scientific fact. It is this: Among slow explosives, or explosive mixtures, the one that makes the best "showing" is the quickest one. Among quick explosives, or detonating compounds, the one that makes the best "showing" is the slowest one.

Taking this rough statement for what it is worth, it is not without reason to support it. To overcome a given resistance and perform work, a certain intensity or rapidity of action is necessary, but if the action is more rapid than necessary it creates difficulties for itself.

If two detonating explosives are equal in chemical attributes, I think the slower of the two will make the best record; that is, give the greatest compression in the crusher gauge. They may have *actually* performed the same work, but the quicker one will encounter a higher resistance and give less compression, consequently. In such a case the question could be decided by measuring the heat developed in the plugs, practically a difficult matter.

By chemical theory the advantage of blasting gelatine over nitroglycerin is very slight, but it makes a decidedly better "showing" in the gauge. I think it is very slow as a detonating explosive, but have no absolute method of proving it. The question whether or not the "showing" in the crusher gauge, as dependent on the relative slowness or quickness of high explosives, represents a real advantage in certain blasting operations, would depend upon the law of change in the particular resistance encountered. If, like copper and lead resistance, it increased with rapidity of action, the advantage would be real. If, on the contrary, it decreased with rapidity of action, the advantage would be unreal. Where a large part of the work consists in moving heavy masses of material, the advantage would be real, as inertia is a resistance which increases with rapidity of action. Where, on the contrary, the breaking of hard rock constituted the chief element of the work, I think the advantage would be unreal.

To illustrate, it has been found that for breaking boulders by surface action, blasting gelatine is inferior to dynamite, being, as I take it, too slow for the work.

Crusher and Cutter Gauges in Guns.

The question at issue here is whether the record of the gauge is to be interpreted as a record of work or a record of pressure.

According to the artillerist, it is a record of maximum pressure. When the record is made in the testing machine it may be considered indifferently a record of either work or pressure.

Let us first consider this operation. The motion of the point of application of the force is so slow that inertia may be neglected, and the pressure and resistance be considered equal. The force develops the low form of copper resistance. Even if we attempt to apply the force suddenly and develop a higher form of resistance, this passes into the low form before we can measure it, the copper yielding enough to establish an equality between the pressure and the low form of resistance. The work is, therefore, the integral of the product of the varying pressure into the differential of the path.

The argument that the gauge record is a record of the highest pressure in the gun is this: a certain path corresponds to a certain maximum pressure, because any pressure less than this will not overcome the resistance up to this point, and any pressure greater than this will overcome the resistance beyond this point, and so extend the path. This reasoning assumes that the action of the powder gases is substantially like that of the testing machine.

In regard to the action of powder in guns, the celebrated English Committee on Explosives said something as follows. I quote from memory, and if the Committee did not say the equivalent of this I will father it myself.

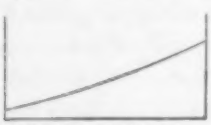
"When a charge is lighted in a gun the pressure rises rapidly to a point a little below the maximum, then more slowly to the maximum at which epoch the shot has just moved. The pressure then falls more or less rapidly, depending upon various circumstances."

We will assume, for the sake of argument, that the time required to give a certain compression or indentation in the testing machine and the time of action of the powder gases in the gun are equal.

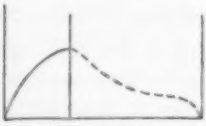
The Rodman theory of the crusher gauge may be illustrated by two rough diagrams, one of which represents the action of the testing machine, the other the action of the powder gases (page 578).

The ordinates represent pressures, the abscissas, times. Neither is a diagram of work; both are diagrams of pressure as related to

time. The powder pressure is only effective in making the record during its passage from zero to maximum, consequently the latter part of the powder curve is dotted.



Testing Machine.



Powder Gases.

The diagrams for the cutter gauge present no differences from the above which make it worth while to specially consider them.

We think this presents the Rodman view very fairly. The argument is plausible. Moreover, it is supported by General Rodman's experiments, also by the English experiments, before alluded to, in which a copper cylinder, compressed by a charge of powder, was used over and over again for the same test without undergoing further shortening.

When I started this discussion I stated my belief that the record of the Rodman gauge was a record of work. That was prejudging the case, but that belief, like any other I may hold, is subject to correction. General Abbot, who is an advocate for work also, makes in this connection a very shrewd remark. He asks: "Why should further motion be communicated to the indenting tool when supported by a surface cut in the copper, which has resulted not only from the maximum action, but from the combined effect of all other actions?"

Having presented the argument for pressure, perhaps the fairest way is to present as strongly as possible the argument for work, reconciling the two views as best we may. We have already seen that working forces present two distinct cases.

The first is the case of a force working so slowly that inertia is not concerned—the resistance it develops at any instant is practically in equilibrio with it. I say practically because the equality is only approximate. If there is absolute equality at any instant the work ceases. This is the case of work in the testing machine. Its characteristic is the absence of kinetic energy. The work is an incidental. The record is a record of pressure.

The second case is that of a dynamic force proper, which is typified by a body moving with a certain velocity and possessing a kinetic energy depending upon this velocity and the body's mass—

that is, it is capable of doing a certain amount of work, and, moreover, it *must* do that amount of work and no other.

Now, the pressure of the powder gases is a static force so long as it does no work, or works so slowly that there is a continuous practical equality between pressure and copper resistance, but it *may* be transformed into kinetic energy by giving motion to the piston.

In the general case, is this force applied gradually as in the testing machine, or do the gases launch themselves against the piston and drive it into or against the copper?

Assuming the circumstances of the action to be given correctly by the latter statement, at or near the beginning of the motion, the powder pressure in running up to its maximum exceeds the corresponding copper resistance. Having received its maximum it will fall more or less rapidly, but the piston will continue to move, notwithstanding that the resistance may then exceed the powder pressure. The energy in excess at the beginning fills the deficiency in the latter part of the path.

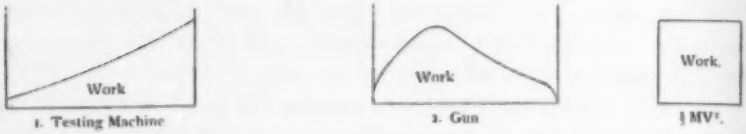
In the testing machine, when the pressure falls below the resistance, the piston comes to rest. Why does it continue to move under the action of the powder gases? Because the force is now kinetic. The energy is stored in the piston by virtue of its inertia, and is given out as required to overcome the resistance till its allotted task is finished.

The attentive reader may say this is the same case as that of work by a falling weight. It is something like it, but there is a radical difference. In one case the force begins as a maximum, as a completed force, and receives no accession during the path. It acts with one impulse. In the other case, that of powder in the gun, the force begins to act on the copper with a very low intensity (determined by the initial resistance of the copper) and receives continual accession throughout the path. In one case the force is impulsive; in the other it is varying and incessant. Moreover, in the first case the path is described in an instant; in the other probably in some fraction of a second. The first is quick compared with anything; the latter is quick compared with some things and slow compared with others. The first action develops the highest limit of copper resistance; the second is prolonged enough to allow this resistance, even if it is developed, to pass into the lower form.

To show the futility of attempting to obtain the pressure from the

work in the case we have been considering, let us construct the crusher diagrams of action (now representing work) for the testing machine and the gun once more.

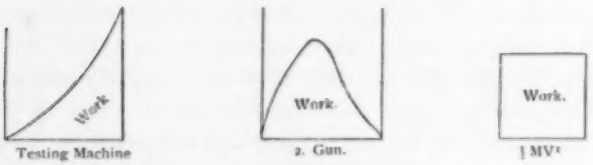
DIAGRAMS FOR CRUSHER GAUGE.



Let the ordinates represent pressures or intensities, and the abscissas paths. The area of the first diagram is the work done in the testing machine. The path being the same in the two diagrams, if we know the form of the curve in the second diagram, we can deduce the varying intensities of the force which, as ordinates, will give the same area or work. But can we consider these intensities powder pressures?

Unfortunately for the hypothesis we cannot, for if we shorten the path, as in the following diagrams for the cutter gauge, the powder

DIAGRAMS FOR THE CUTTER GAUGE.



charge and, therefore, the work, being the same, we must reckon a higher intensity for the gun diagram, although the action of the gases in the gun must have been the same.

We see, therefore, that when the record in the gun is to be interpreted as *work* there is no way of obtaining the *absolute* intensity of the force, as represented by pressure in the bore. The only safe relative measure then for the force is the square root of the work.

Our next purpose is to show that the distinction between interpreting the gun record as work and interpreting it as pressure is radical, and that it is necessary in any given case to choose between them.

By putting in the bore of the gun either a cutter or crusher gauge, or both, we cannot alter the circumstances of the powder action. If the record is one of work, the work shown by the two gauges will be the same; if it is a record of pressure, the pressure shown by the two will be the same. I propose to show that generally, if the pressures agree, the works will disagree, and *vice versa*.

My first step has been to prepare certain tables showing the relation between work, pressure and path, as deduced from the action of the testing machine for both cutter and crusher gauge. These have been prepared from the data of the Rodman tables and the corresponding curves which give the relation between pressure and path. By integration of the area corresponding to a given path (that is, the area between the curve, axis of paths, and extreme co-ordinate representing the pressure), I first constructed tables of the work corresponding to a series of paths for both instruments, then curves showing this relation, from which curves I could obtain the interpolations more readily. From these curves (see Plate IV, Fig. 3, in which they are plotted on a small scale) I took the required data.

My original data consisted of the Rodman scale of pressures for the crusher, prepared at Frankford Arsenal, and the Rodman scale of pressures for the double wedge or pointed cutter used by General Abbot.

It was my intention to include in the scope of my work the *curved cutter*, now generally used by the Ordnance Department, and I did a good deal of work in this direction before I became convinced that my data was insufficient for the purpose. The cutter was obtained from the National Armory, being part of the equipment of a new .30 calibre rifle for testing smokeless powders. The edge of the cutter was the arc of a circle 3 inches in diameter, the cutting angle being 60° and the piston $\frac{1}{30}$ square inch in cross section. I received a scale of pressures with the cutter extending from 20,000 pounds to 79,000 pounds on the square inch, corresponding to *lengths* of cuts from .498 to .806 inches. I computed the paths, that is, indentations, from a table of natural sines and reduced them to feet, the corresponding pressures being divided by 30, and found my extreme pressures 667 and 2633 pounds, and my extreme paths .00173 and .00460 feet. This left a wide gap near the origin of the curve I desired to plot.

I attempted to fill this gap, and at the same time determine the initial resistance by placing weights on the piston without shock and determining the corresponding indentations in copper. The copper used was the kind recommended by the Springfield authorities, obtained from Moffet, of New York. I got *four* satisfactory interpolations in this way, and concluded that the initial resistance was very small, probably about 10 pounds.

However, when I came to plot the curve I found the armory data gave me nearly a straight line (curving slightly the wrong way), which offered no promise of reaching the origin without a violent change of direction; instead it pointed to a large negative resistance at the origin. I therefore concluded that this scale had not been determined in the usual testing machine, and reluctantly gave up the task of going further with the matter. The following is an abridged table of the data used in plotting the unfinished curve, which will be found on Plate IV, Fig. 2. The first four items in the table are mine. The rest were computed from the Springfield scale of pressures.

Relation Between Pressure and Path. Curved Rodman Cutter $\frac{1}{36}$" Piston. Edge Arc of 3" Circle. Most of Data from Scale of Pressures Prepared at the National Armory, April, 1891.

Length cut (inches).	Path depth of cut (feet).	Pressure (pounds).	
.028	.000005	13	These data were obtained by placing weights on the piston without shock, the cutter edge resting on copper.
.068	.00003	17	
.131	.00012	41	
.298	.00062	313	
.498	.00173	667	Armory data.
.522	.00191	800	
.546	.00209	933	
.570	.00228	1,067	
.615	.00266	1,333	
.658	.00304	1,600	
.699	.00344	1,867	
.738	.00384	2,133	
.775	.00424	2,400	
.806	.00460	2,633	

For the sake of convenience in studying the subject, I have arranged the data relating to work, pressure and path for the crusher and pointed cutter gauges into three tables. The first is arranged with reference to work, the second with reference to pressure, the third with reference to path.

A cursory examination of these tables shows (see also curves on Plate IV, Fig. 3):

1. Work being the same
   - Pressure.
     - Cutter > crusher, except for very small work.
   - Path.
     - Crusher > cutter, except for moderate and small work.

2. Pressure being the same
   - Work.
     - Crusher > cutter.
   - Path.
     - Crusher > cutter, except for very small pressures.

3. Path being the same
   - Work.
     - Cutter > crusher, except for very small paths.
   - Pressure.
     - Cutter > crusher, except for small paths.

Relations of Work, Pressure and Path. Crusher and Cutter Gauges in Rodman Testing Machine. Arranged for Work.

Work (Foot-pounds).	Pressure (pounds).		Path (feet).	
	Crusher (cylinders).	Cutter (pointed) (discs).	Crusher (cylinders).	Cutter (discs).
0.1	550	230	.00019	.0010
0.5	699	630	.00082	.00195
1	863	965	.00146	.00260
2	1,151	1,560	.00241	.00343
3	1,370	1,940	.00319	.00399
4	1,564	2,400	.00387	.00447
5	1,716	2,740	.00448	.00486
6	1,865	3,100	.00504	.00520
8	2,103	3,660	.00605	.00580
10	2,313	4,300	.00696	.00630
12	2,514	4,830	.00779	.00674

Work (Foot-pounds).	Pressure (pounds). Crusher (cylinders).	Pressure (pounds). Cutter (pointed) (discs).	Path (feet). Crusher (cylinders).	Path (feet). Cutter (discs).
14	2,680	5,300	.00856	.00713
16	2,845	5,780	.00929	.00748
18	2,975	6,250	.00990	.00780
20	3,115	6,700	.0106	.00865
25	3,434	8,000	.0121	.00870
27	3,545	8,640	.0127	.00895
30	3,745		.0135	
35	4,020		.0148	
40	4,320		.0160	
45	4,585		.0171	
50	4,854		.0183	
55	5,134		.0192	

Relations of Work, Pressure and Path. Crusher and Cutter Gauges Treated in Rodman Testing Machine. Arranged for Pressure.

Pressure (pounds).	Work (foot-pounds). Crusher (cylinders.)	Work (foot-pounds). Cutter (discs).	Path (feet). Crusher (cylinders).	Path (feet). Cutter (discs).	
1,000	1.3	1.05	.0017	.0027	
2,000	7.0	3.20	.0056	.0040	
3,000	18.1	5.75	.0101	.0051	
4,000	34.7	9.00	.0147	.0061	
5,000	52.6	12.80	.0186	.0069	
6,000	70.5 (?)	16.80	.0216 (?)	.0076	(?) Doubtful, beyond the limits of the curves.
7,000		21.00		.0082	
8,000		25.00		.0087	
9,000		28.10		.0091	

Relations of Work, Pressure and Path. Crusher and Cutter Gauges in Rodman Testing Machine. Arranged for Path.

Path ($\frac{1}{1000}$ feet.)	Pressure (pounds). Crusher (on cylinders).	Pressure (pounds). Cutter (on discs).	Work (foot-pounds). Crusher (cylinders).	Work (foot-pounds). Cutter (discs).
1	800	235	0.75	0.106
2	1,050	650	1.7	0.53
3	1,320	1,250	2.7	1.47
4	1,580	1,950	4.2	3.07
5	1,845	2,900	5.8	5.49
6	2,070	3,940	7.7	8.90
7	2,313	5,120	10.0	13.43
8	2,540	6,640	12.2	19.80
9	2,760	8,800	14.9	27.47
10	2,975		18.0	
12	3,400		24.5	
15	4,060		35.5	
20	5,360		59.5	

The tables and curves have involved considerable labor, but they may serve to help some student of the subject. We can show their utility by a practical case. Suppose both cutter and crusher gauges to be used in a gun, and that the path (compression) for the crusher is .0060 feet, for the cutter (indentation) .0041 feet. The corresponding pressures are 2,070 and 2,050 pounds. The corresponding works are 7.7 and 3.25 foot-pounds. In this case the record would be one of pressure since the pressures are practically equal, while the work for the crusher is more than double that for the cutter.

But suppose the path for the crusher to be .00448, while that for the cutter is .00486 feet. The corresponding pressures will be 1,716 and 2,740 pounds, while the work will be 5 foot-pounds for each. The record in such a case is a record of work since the pressures disagree.

This would make the question one of fact, to be determined by a comparison of the records of the two instruments, and when we can bring a question to this satisfactory state there is little room left for argument. We may make some effort, however, to reconcile the two views of the question which we have tried to present fairly and which we now see are incompatible in any particular case. If one is right, the other is wrong. The fact is, we know very little about the action of powder gases. Both views rest upon simple but contrary hypotheses in regard to this action—one that the powder acts so slowly that pressures and resistances are virtually in equilibrio, the other supposes this action to be quick enough to be converted into kinetic energy. In the first case no kinetic energy is developed—the record is pressure. In the second case the energy is entirely kinetic, and the record is work.

Now gunpowder covers a great range of sizes of grain. Between grains 1.5 inches in diameter and fine grained rifle powder there is an immense gap. The time of burning may be taken directly proportional to the diameter of the grains, perhaps giving a ratio of 100 : 1 in the times of action for the two cases. Time of action determines whether the powder gases will act as a pressure or kinetically. It is possible, therefore, that one view is applicable to the coarse powder and the other to the fine.

The only suggestion of value I have to offer as an outcome of the study given to the subject is this: *by using two gauges presenting*

different resistances, the question in regard to the interpretation of the record becomes one of fact to be determined by a comparison of the two records.

All then that is required to solve the question generally is certain data of this nature, data which I unfortunately lack.

For slow-burning powders I have no doubt that the Rodman principle is reliable. This was the case it was designed to meet. I have too much admiration for this original thinker, as well as respect for the accomplished corps of officers who have followed in his footsteps, to lightly criticise his work, even if I thought there was a chance to do so, but I wish to state my belief that the Rodman principle is perfectly reliable for the cases to which he intended it to be applied.

But I do not believe that the Rodman gauge can be used to determine the pressures of fine-grained quick powders in small arms. I regret that I cannot support this by experimental data as I had hoped to do in time for this paper.

Whether or not the record in such a case is a reliable one of work would depend upon whether or not the *whole* energy of the powder acts kinetically.

It is hard to conceive that there should be an exact point at which the record ceases to be a pressure and becomes work, in fact, impossible.

It would seem from this that there may be such a thing as a mixed action.

We have always, however, our criterion—the agreement or disagreement of the two gauges. If they agree upon pressure, the record is pressure. If they agree upon work, the record is work. If they agree in neither, then there has been a mixed action, and a comparison gives either one or the other predominence. It is evident, I think, that a valuable study of the particular powder may be made in this way, and a good idea may be formed of its mode of action in the gun.

Professor Bartlett suggested in his original criticism of General Rodman's scheme the use of a series of measured initial resistances of different intensities as a substitute for the Rodman gauge. The English experimenters in using a cylinder already compressed virtually applied this principle. The compression not being increased, they assumed very properly that the pressure did not exceed the

figure corresponding to the first compression. But this was a typical case of slow-acting powder giving a record of pressure.

Does this prearranged initial resistance, approximating the final resistance developed by the powder action, present any special advantage in gauging quick powders? It may be said, in its favor, that the force cannot act kinetically unless it can overcome the initial resistance, but it can also be said *per contra* that if it *does* act kinetically it *will* overcome the resistance, as illustrated by my experiments in the foot-pounds machine. It may be remembered that I took copper cylinders very highly compressed and dropped the weight on them from very minute heights, in every case getting a record of work.

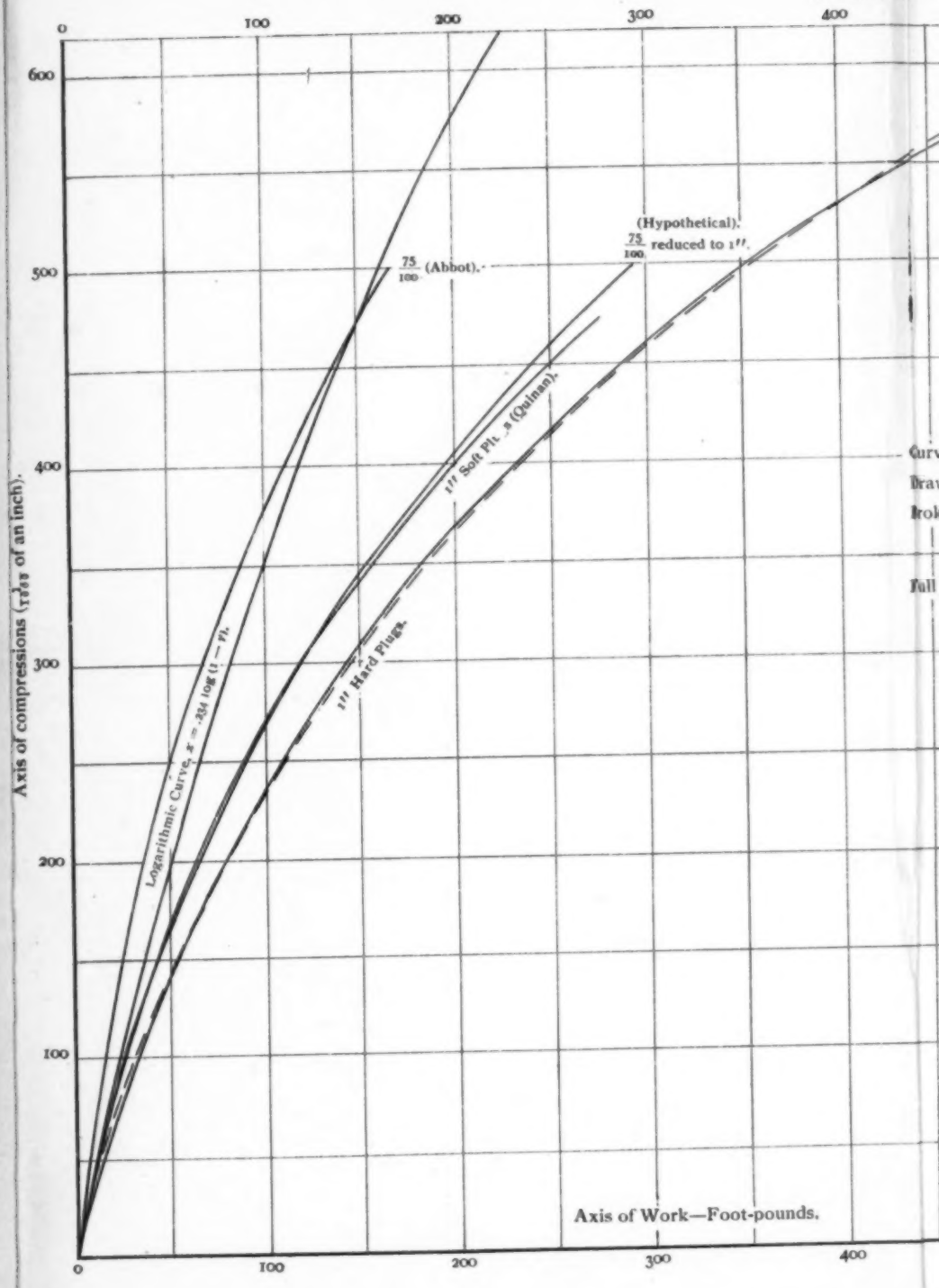
It does not seem to me, therefore, that this plan entirely overcomes the difficulty of obtaining an absolute figure for the pressure, when the record made in the ordinary way would be an unequivocal record of work. It simply shortens the path and shows a corresponding high intensity of action, when a longer path, as in the ordinary case, would show a less intensity. The difficulty would be this: as the force is certain to act, the higher the initial resistance is set the higher the pressure that would be credited to the powder.

In mixed actions, however, this plan might serve a good purpose in determining the mode in which the powder would act. The piston would have no chance to acquire living force by moving over a comparatively unguarded path. I think, therefore, that in the general case of quick powders an initial resistance would be useful in converting a doubtful record into a record of pressure. However, the conclusions in such a case should be checked by using two different instruments.

It is possible that no explosive used in fire arms is capable of writing a record of work which will agree in two such different instruments as the cutter and crusher gauges. This we cannot settle positively, but think that the fine grained smokeless powders proposed for small bore rifles may do so. In dealing with these agents we are really dealing with high explosives, although under a new form possessing new properties. The condition required for explosion is analogous to the condition for detonation—pressure for one and shock for the other. Smokeless powders are feeble or strong in proportion to the initial pressure which causes explosion. In gunpowder the burning is progressive, and the velocity of combustion

is independent of the pressure. In smokeless powder the burning is, or should be, progressive, but the velocity of combustion is directly dependent on the pressure. Between conditions which will not cause it to burn at all, and conditions which will cause it to explode violently, the step is very short. Finally it differs from gunpowder in this: the gunpowder reaction is external between molecules, the smokeless powder reaction is internal between atoms in the same molecule. These differences would seem to show that caution should be exercised in applying the same tests to the two explosives. In suggesting the use of the two gauges, we think we have indicated a method of working which will throw light upon the action of the newer agent.

PLATE

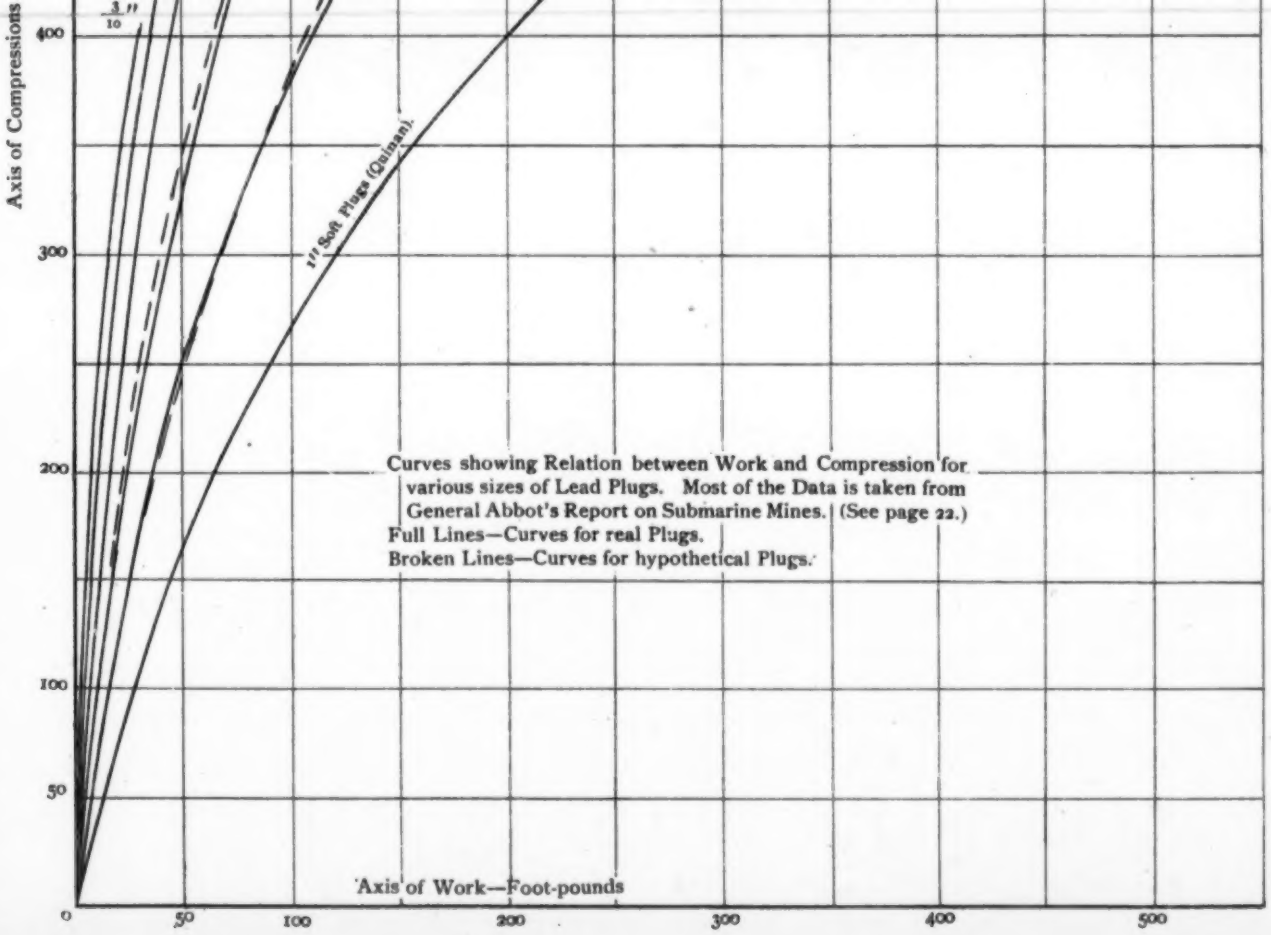

0
100
200
300
400
600
500
400
300
200
100
0
100
200
300
400
Axis of compressions (1/100s of an inch).
Axis of Work—Foot-pounds.
75/100 (Abbot).
(Hypothetical).
75/100 reduced to 1".
1" Soft Pl. 8 (Quinan).
1" Hard Plugs.
Logarithmic Curve, s = .334 log (1 − f).

LATE I.

Curves showing Relation between Work and Compression of Drawn Lead Plugs—one inch Diameter, one inch long.

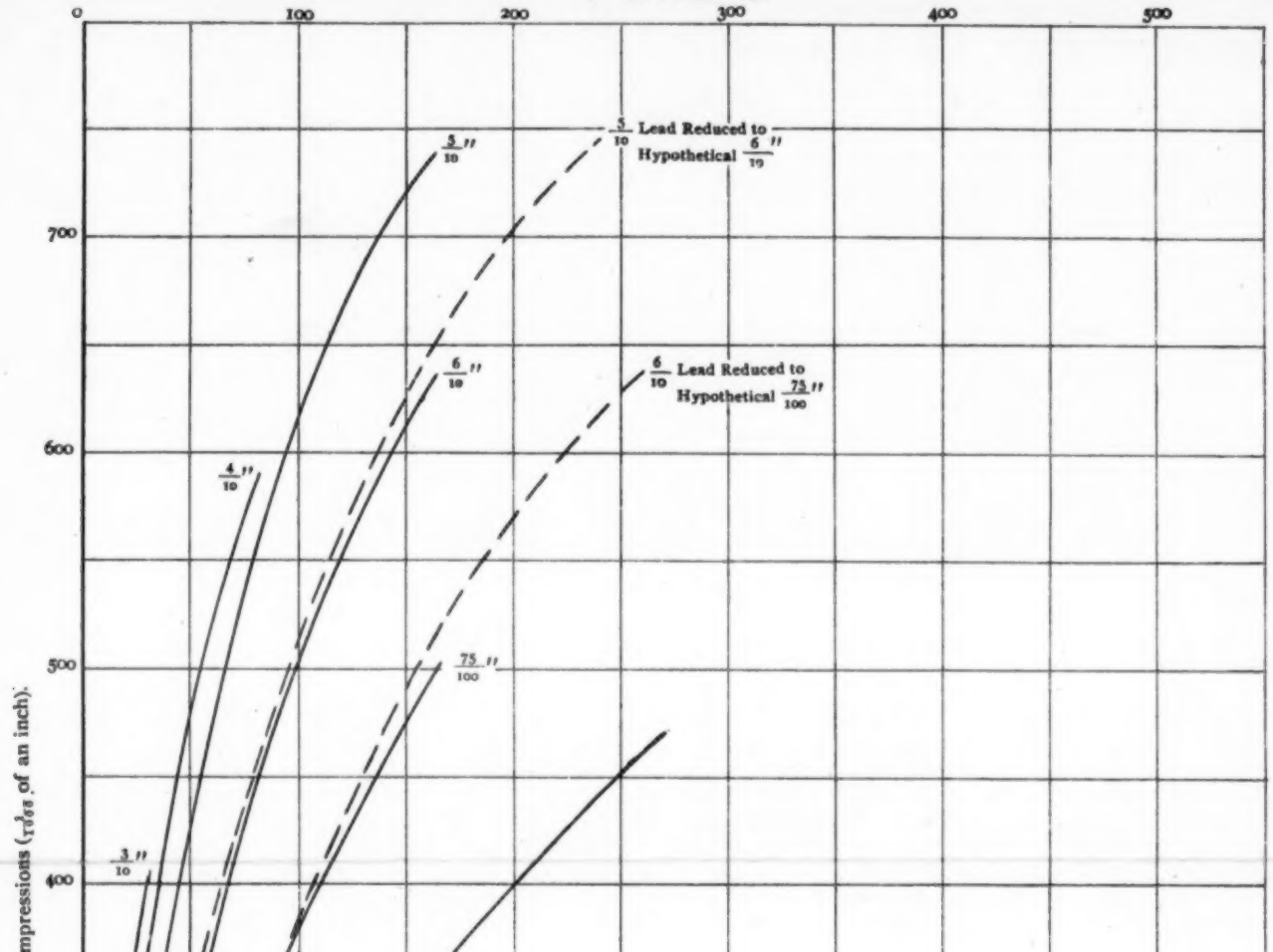
Broken Line—Curve determined by Practical Experiments with falling Weight.

Full Line—Curve determined by Equation $x = \frac{190y^{1.1}}{1000 - y}$ x = foot-pounds. y = comp'n in $\frac{1}{1000}$".



Curves showing Relation between Work and Compression for various sizes of Lead Plugs. Most of the Data is taken from General Abbot's Report on Submarine Mines. (See page 22.)
Full Lines—Curves for real Plugs.
Broken Lines—Curves for hypothetical Plugs.

PLATE II.


0
100
200
300
400
500
700
600
500
400
$\frac{5}{10}$ Lead Reduced to Hypothetical $\frac{6}{10}$"
$\frac{6}{10}$ Lead Reduced to Hypothetical $\frac{75}{100}$"
$\frac{5}{10}$"
$\frac{6}{10}$"
$\frac{4}{10}$"
$\frac{75}{100}$"
$\frac{3}{10}$"
Compressions ($\frac{1}{1000}$ of an inch).

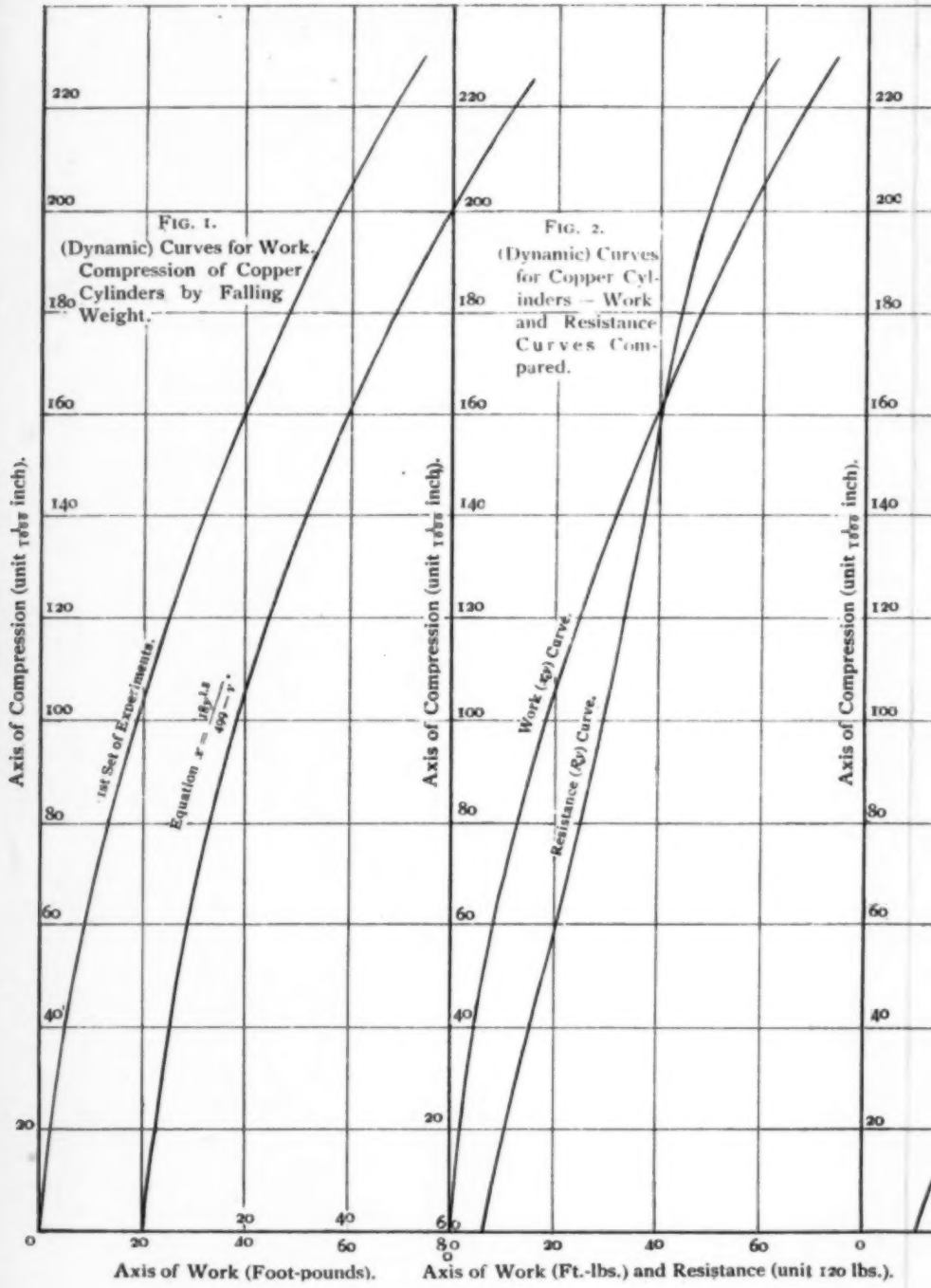


FIG. 1.
(Dynamic) Curves for Work. Compression of Copper Cylinders by Falling Weight.

FIG. 2.
(Dynamic) Curves for Copper Cylinders — Work and Resistance Curves Compared.

PLATE III.

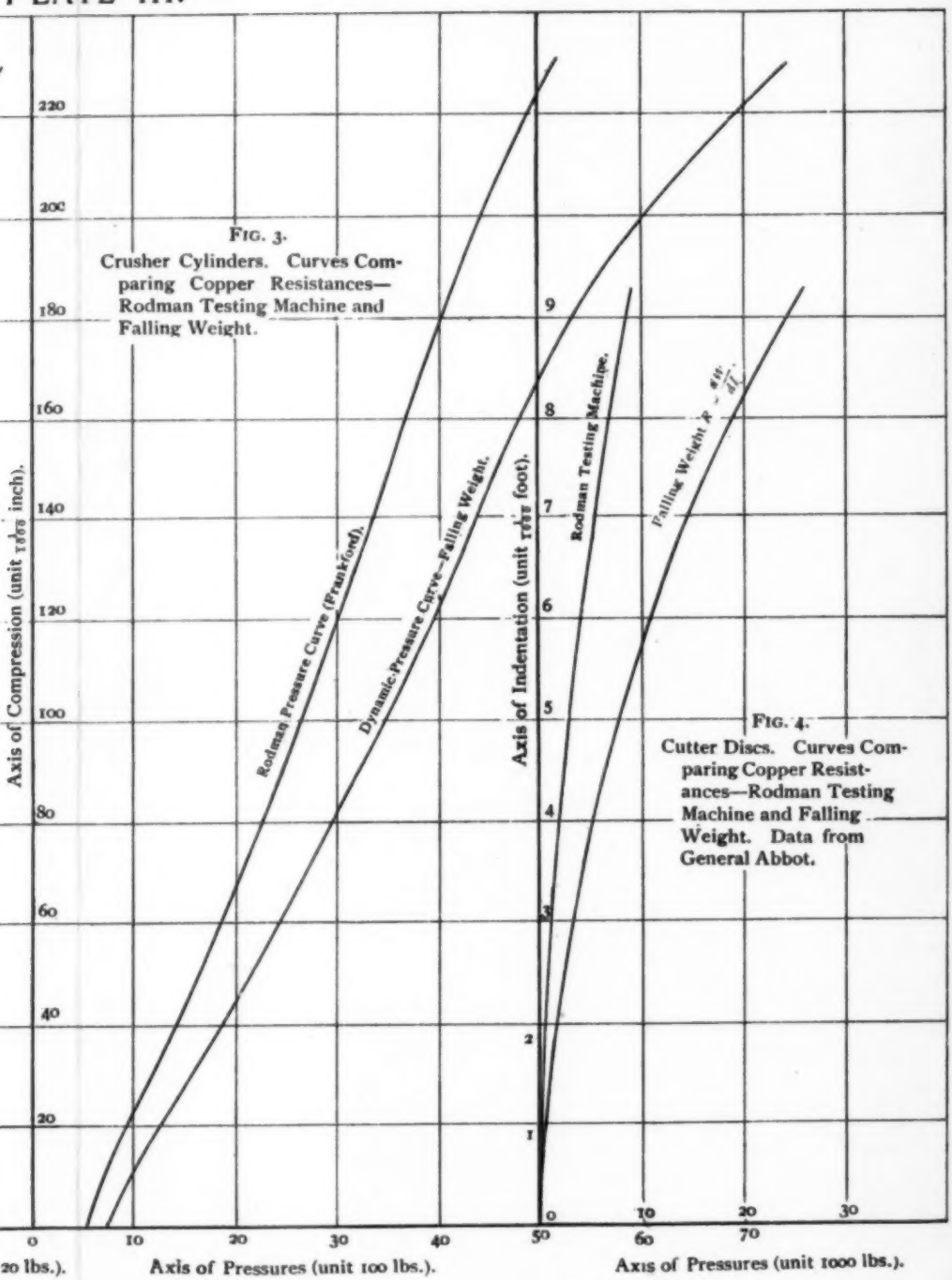


FIG. 3.
Crusher Cylinders. Curves Comparing Copper Resistances—Rodman Testing Machine and Falling Weight.

FIG. 4.
Cutter Discs. Curves Comparing Copper Resistances—Rodman Testing Machine and Falling Weight. Data from General Abbot.

PLATE IV.

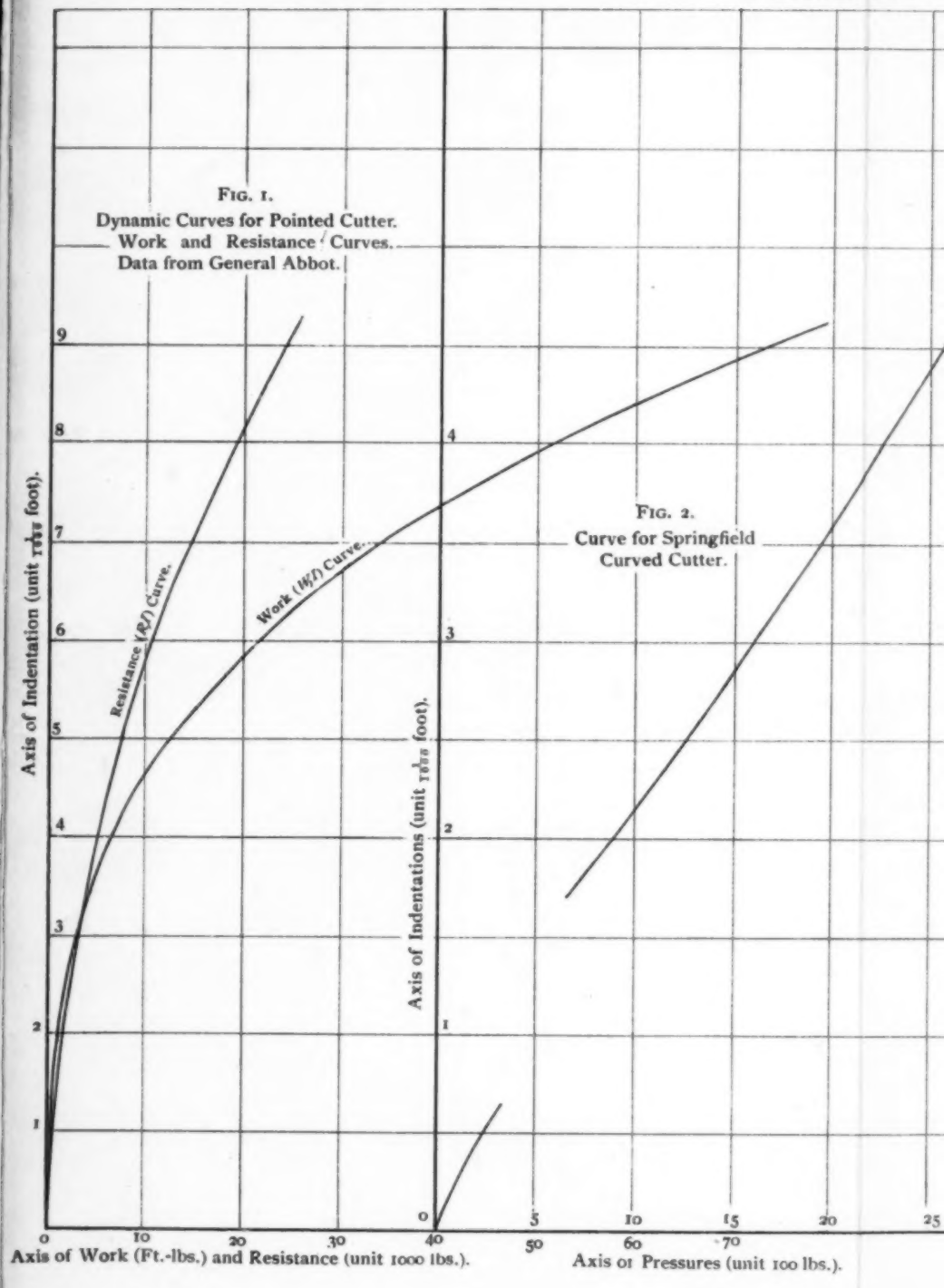


Fig. 1.
Dynamic Curves for Pointed Cutter.
Work and Resistance Curves.
Data from General Abbot.
Resistance (R,f) Curve.
Work (H,f) Curve.
Axis of Indentation (unit 1/100 foot).
Axis of Indentations (unit 1/100 foot).
Axis of Work (Ft.-lbs.) and Resistance (unit 1000 lbs.).
Fig. 2.
Curve for Springfield
Curved Cutter.
Axis of Pressures (unit 100 lbs.).

IV.

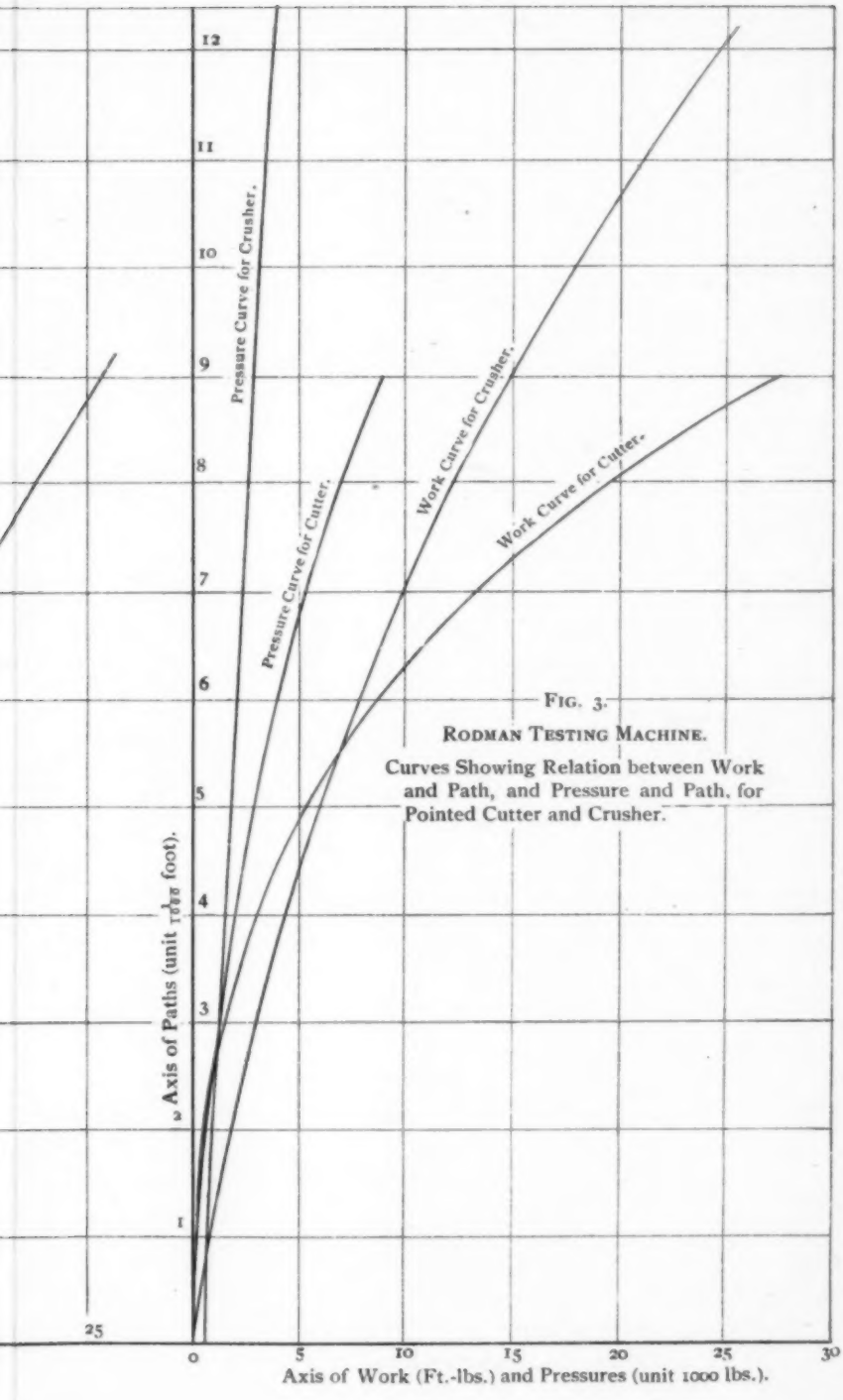


FIG. 3.

RODMAN TESTING MACHINE.

Curves Showing Relation between Work and Path, and Pressure and Path, for Pointed Cutter and Crusher.

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U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

PIGEONS FOR SEA SERVICE.

WITH AN ACCOUNT OF THEIR USE DURING THE LAST SUMMER CRUISE OF THE U. S. P. S. CONSTELLATION.

By Assistant Professor H. Marion, United States Naval Academy.

Nearly all the European governments have recognized the value of homing pigeons for land and sea service, and have established numerous military pigeon posts in the interior and along the coasts, under direct control of the Government.

In France, Germany, Austria, Italy, Spain, and Portugal, the organization of military pigeon posts is very complete. It has been extended to Russia, Denmark and Sweden; and even Africa has been brought into communication with Spain by stations at Ceuta and Mellila. England has recently established a station of considerable strategical importance at Gibraltar, insuring communication with Tangier and vessels cruising in the vicinity of the Straits of Gibraltar. The chief columbary of the Admiralty is situated at the Scilly Islands.

Italy has been particularly active of late in establishing pigeon posts for naval purposes to be used in connection with the manœuvres of her new fleet. For example, there is a military pigeon post at Rome, and another at the Island of Maddalena, and the birds belonging to them alternately fly from one loft to the other in very good time. The total distance is 170 miles, and that over water 150 miles. These pigeons have flown on several occasions at the rate of 28, 29 and 30 miles an hour. A longer distance at sea has also been made by them.

Another military loft is situated at Cagliari, Sardinia, which constitutes part of the Cagliari-Napoli line. The distance between those two places is 294 miles. Birds liberated at sea from Italian vessels have made a distance of as much as 287 miles over the sea at about 31 miles an hour.

Canada has followed the example of the European countries by establishing a connected system of pigeon stations throughout the Dominion, extending from Halifax to Windsor, and connecting her principal seaports with the interior.

The accompanying chart I., showing the system of military pigeon posts in Europe, gives an adequate idea of the importance of this new branch of the service. Each one of the lines upon the map shows a pigeon route. In most cases there is a double post, that is to say, there are relays of pigeons at each end of these lines, so that, by exchanging birds, a double service is insured. Other lines are still more perfected, the same birds performing a double duty, being used for a "there-and-back" flight.* The employment of pigeons for military purposes, therefore, may be considered as established, and the value of this service as no longer requiring to be proved.

We have frequently urged in these PROCEEDINGS (Nos. 47, 48 and 54) the adoption of a similar system at the principal seaports and naval stations of the Atlantic coast. So far no organized system of pigeon posts has been established in the United States, although numerous experiments made in this country have fully demonstrated the great value and usefulness of such a service, especially for naval purposes.

The most important of these experiments, and the most successful in its results, was made under the direction of Commander C. M. Chester, U. S. N., during the last summer cruise of the U. S. P. S. Constellation.

We quote, by permission, some extracts from the interesting and most carefully prepared report of Lieutenant W. S. Benson, U. S. N., who took an active part in the experiments.

"On June 6, the day the Constellation sailed from Annapolis, ten pigeons from the Naval Academy loft were taken on board and released at different distances down the Chesapeake Bay, the last at

* This remarkable result can only be obtained over short distances, not exceeding 50 miles, by long and careful training, feeding the birds at one end of the line, and keeping their mates and young ones at the other.

CHART I.

CHART SHOWING THE SYSTEM OF MILITARY PIGEON POSTS IN EUROPE.

[*Reproduced, by permission, from Mr. Tegetmeier's article in the Journal of the Royal United Service Institution, Vol. XXXVI, No. 171. Published originally in La Nature.*]

FRANCE.—1, Mont Valérien; 2, Paris; 3, Vincennes; 4, Lille; 5, Douai; 6, Valenciennes; 7, Maubeuge; 8, Mézières; 9, Verdun; 10, Toul; 11, Langres; 12, Belfort; 13, Besançon; 14. Lyon; 15, Marseille; 16, Perpignan; 17, Grenoble; 18, Briançon; 19, Toulon.

PORTUGAL.—1, Lisbonne; 2, Porto; 3, Valence; 4, Chaves; 5, Bragance; 6, Almeida 7, Guarda; 8, Coimbre; 9, Castello Branco, 10, Abrantès; 11, Elvas; 12, Peniche; 13, Beja; 14, Lagos.

ESPAGNE.—1, Madrid; 2, Figueras; 3, Iaca; 4, Pamplona; 5, Oyarsun; 6, Ferrol; 7, Ciudad-Rodrigo; 8, Badajoz; 9, Tarifa; 10, Ceuta; 11, Melilla; 12, Palma; 13, Mahon; 14, Zaragoza; 15, Valladolid; 16, Cordoba; 17, Malaga; 18, Valencia.

ITALIE.—1, Rome; 2, Ancone; 3, Bologne; 4, Vérone; 5, Plaisance; 6, Alexandrie; 7, Mont Cenis; 8, Fenestrelle; 9, Exiles; 10. Vinadio; 11, La Maddalena; 12, Cagliari; 13, Gaeta; 14, Génova.

SUISSE.—1, Thun; 2, Bâle; 3, Zurich; 4, Weesen.

ALLEMAGNE.—1, Berlin; 2, Cologne; 3, Metz; 4, Mayence; 5, Wurtzbourg; 6, Strasbourg; 7, Schwetzingen (en projet); 8, Wilhelmshaven; 9, Tonning; 10, Kiel; 11, Stettin; 12, Dantzig; 13, Kœnigsberg; 14, Thorn; 15, Posen; 16, Breslau; 17, Torgau.

AUTRICHE.—1, Comorn; 2, Cracovie; 3, Franzenfeste; 4, Karlsburg; 5, Serajewo; 6, Mostar; 7, Trieste.

DANEMARK.—1. Copenhague.

SUÉDE.—Carlsborg.

RUSSIE.—1, Brest Litovsk; 2, Varsovie; 3, Novo-Georgievsk; 4, Ivangorod; 5, Luninetz.

a distance of 35 miles, and two and a half hours later the messages were received in Annapolis. One of these birds carried an important message to the Superintendent of the Naval Academy requesting that certain stores that had been omitted from the outfit be sent down to the ship by the Phlox.

"All of the birds liberated returned in good time, and all messages were safely delivered.

"On the return of the Constellation in August, some of these same birds were used at distances of 60 miles, in each case carrying important messages regarding the Constellation to the Superintendent. A few days later these same pigeons were liberated at a distance of 75 miles from Annapolis; all returned, delivering the messages sent in each case. Subsequently they were successfully used at a distance of 100 miles. Nine pigeons were taken on board June 6, belonging to the loft of R. B. Caverly, of Washington, D. C. They were liberated at points in the Chesapeake Bay, and at sea, the last batch being liberated in latitude 38° 6′ N., longitude 74° 10′ W. (180 miles from Annapolis, 200 miles from Washington). All of these pigeons returned to their lofts carrying messages.

"Previous to the departure of the Constellation from Newport on the return trip to Annapolis, in August, through the exertions of E. S. Starr, of Philadelphia, at the request of Professor Marion, pigeons were sent to the ship from lofts in Philadelphia, Woodberry, N. J., Atlantic City, Providence and Fall River. During the six days the vessel was at sea, several birds were liberated at 9 A. M. each day (except one when the weather was threatening, with a strong breeze from northward), bearing duplicate messages giving the ship's position, condition of weather for the past twenty-four hours, and other items of interest. In nearly every case these messages were delivered at the respective lofts the same day and the messages repeated to the Superintendent of the Naval Academy by telegraph. The greatest distance from land any birds were liberated was about 90 miles; and those liberated to the northward of their lofts had previously only been flown from the southward, and the owners were under the impression that they could be used successfully only from the southward. Their success showed that pigeons could be flown from *any* direction."

These results show that the pigeon service from *ship to shore* was entirely successful.

Another experiment in the opposite direction, namely, from *shore to ship*, was less conclusive, as the birds used in this experiment had been put on board at short notice and were not yet thoroughly domesticated when used. In spite of this disadvantage, some good, and even unexpected, results were obtained. We again quote from Lieutenant Benson's interesting report.

"Before leaving Annapolis, ten pigeons (also taken from the Naval Academy loft) were sent on board the Constellation and placed in a cote secured on the spar-deck capstan on the quarter-deck. Nearly all these were young birds, two only one month old. The cote was left closed until the 19th, when it was opened and all were allowed to fly about the vessel, then at anchor off New London. The pigeons flew about the Constellation, other vessels in the harbor, and on shore. Before night all had returned to the cote except two, one old, the other young. . . . After this the cote was opened every day when the weather was good, and in a very short time the pigeons became accustomed to the unusual noises of the people about decks, flapping of sails, wash-clothes, etc., and would return to the cote even when the awnings were spread which concealed the cote from view. Four of these birds were frequently taken ashore, out in boats, and to other vessels, and they always returned. They were taken from three to four miles over land and out of sight of the shipping and still returned. It was observed, however, that they did not always go directly to their own ship, but would light on other vessels near. On several occasions they were taken ashore and not liberated till the ship had left her anchorage and was *several miles out*, under sail and light yards down, and yet they got back in very good time."

This experiment, however limited in its scope, opens a new field for the usefulness of homing pigeons for naval purposes. They might be used, for instance, to carry news from a landing party to a vessel stationed or cruising at a short distance from the shore or for communications between the different vessels of a squadron.

In concluding his report Lieutenant Benson says:

"I beg leave to add that, from the successful employment of homing pigeons on land at all distances, and the work done by those on the Constellation, the conclusion must be accepted that their field of usefulness is unlimited. On land, where all points can usually be reached by telegraph, their employment is more in the

nature of a pastime; though under certain circumstances they might be of great value even on land [as, for example, during the siege of Paris]. But to the navy and seafaring peop'e they are simply of inestimable value. The idea advanced in Professor Marion's paper * on the subject of establishing a regularly organized service with lofts at all our naval stations cannot be too strongly advocated. In order, however, to be successful, I am thoroughly convinced that the service must be well organized and the pigeons well trained. It is a well-known fact that the principal European governments not only have such a service, but offer every inducement to private enterprise in this direction. The frequent trips made by our different vessels along our coast offer every facility for training pigeons from all the various lofts that might be established. By sending a number of birds on every outward bound vessel the pigeons would have numerous flights over the routes for which they were intended, and could thus be relied upon in case of actual necessity, and the people using them would also gain experience in their use, which would be of no small importance; thus in time of peace giving them practice and training as well as often sending back valuable information. Their value in time of war cannot be estimated. Suppose, for example, that a small cruiser left one of our seaports and, off the coast, unexpectly sighted an enemy's fleet; eight or ten hours notice might be given, thereby saving millions of dollars worth of property as well as the ignominy of defeat.

"The most important fact to be remembered is that when these birds are properly trained and used under a well-organized system they offer an almost sure means of quick communication where none other could possibly be employed. In order to be satisfactory there must be a well-organized system, men who understand handling and breeding the birds, and the best means of sending messages. Every effort should be made to secure and breed the best birds only, and they should be constantly exercised over the route it is intended to use them on, so that no time will be lost when they bear important messages in working out the nearest line of flight.

"The fact having been clearly demonstrated that homing pigeons can be successfully employed to carry messages from vessels at sea to shore stations opens a field of usefulness to the naval service that is inestimable. The numerous ways in which they can be employed

* Proposed Naval Messenger Pigeon Service, No. 54, PROCEEDINGS NAVAL INSTITUTE.

is so apparent that it would be superfluous to dwell upon it in this report.

"As to their use in carrying messages from shore to vessels at sea there is not sufficient data to say positively how far they could be depended upon; but judging from what has been done, we are justified in believing that with proper training and care they could be fully relied upon as messengers."

The foregoing report has been strongly endorsed by Commander C. M. Chester, under whose direction these experiments were made, and he recommends that an appropriation be asked of Congress to carry out the proposed plan of such a service. No appropriation having having been available for this purpose in the past, the expense has been mainly met by private subscriptions, which are not likely to continue.

A system of naval messenger pigeon lofts to be situated at the principal navy yards and stations of the Atlantic coast could be established at a very small expense to the Government and would be of great practical value, even in time of peace, as vessels cruising along the coast from Portland, Me., to Galveston, Tex., could thus keep in constant communication with the mainland and be located at any time during their entire course.

We suggest a connected system of twelve main naval messenger pigeon lofts to be situated at the following navy yards and stations:

1. Portsmouth.
2. Boston.
3. Newport.
4. New London.
5. New York (Brooklyn).
6. Philadelphia (with an annex at Cape Henlopen).
7. Washington (Central Station).
8. Annapolis (Naval Academy).
9. Norfolk (with an annex at Cape Charles.)
10. Port Royal.
11. Key West.
12. Pensacola.

The greatest distance being between the last four stations, some intermediate posts would be desirable between them to insure a connected service. The system could be extended and completed by establishing secondary stations at Cape Hatteras, Wilmington, N. C., St. Augustine, Jupiter Inlet, and Tampa, Florida, and extreme stations at each end—Portland, Me., and Galveston, Tex.

Chart II. shows the position of the U. S. P. S. Constellation when birds were liberated during the last summer cruise. It also

shows the proposed naval messenger pigeon stations along the Atlantic coast with circles of 240 miles radius around each station, indicating the zone in which trained pigeons could be relied upon to return to their home station with a sufficient degree of certainty. The distance is equal to one day's run of a vessel making ten knots an hour, and it could be covered by a pigeon in about eight hours, at an average speed of 30 miles an hour, thus gaining 16 hours on the vessel. Although homing pigeons have flown twice that distance in a day, it is undesirable, for practical purposes, to exceed that limit. From these lofts a vessel leaving any of these stations could be supplied with trained pigeons to be liberated at intervals within the prescribed zone of the station to which they belong.

The message to be sent is written on fine tissue paper, which, rolled up, is inserted into a section of goose quill, then sealed at both ends and firmly fastened to one of the middle tail feathers of the bird by means of a thin copper wire.

To insure safe delivery, each message is duplicated, in cipher if necessary, and forwarded by two or more different birds, liberated at the same time, as they help each other in finding their way home. For long distance flights the birds must be liberated as early in the day as possible.

Advantages of an Organized Service of Messenger Pigeons.

A service of messenger pigeons for naval purposes could not be improvised at short notice, and the birds would require long and careful training before being of any use as bearers of messages.

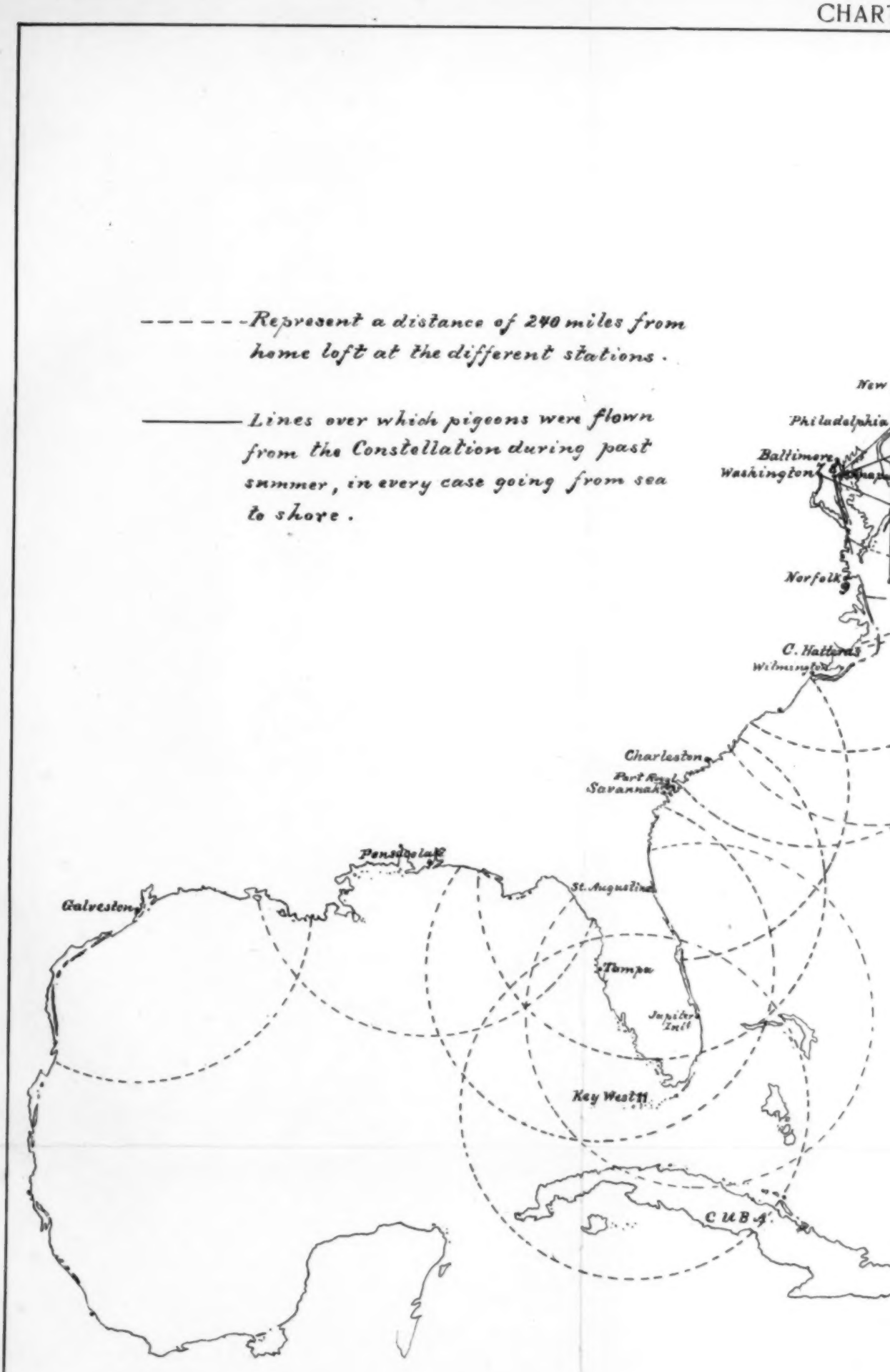
In time of peace or war the occasions are innumerable when pigeons could be used with advantage as messengers when no other means of communication are available. In a recent article in Outing Mr. Gifford says:

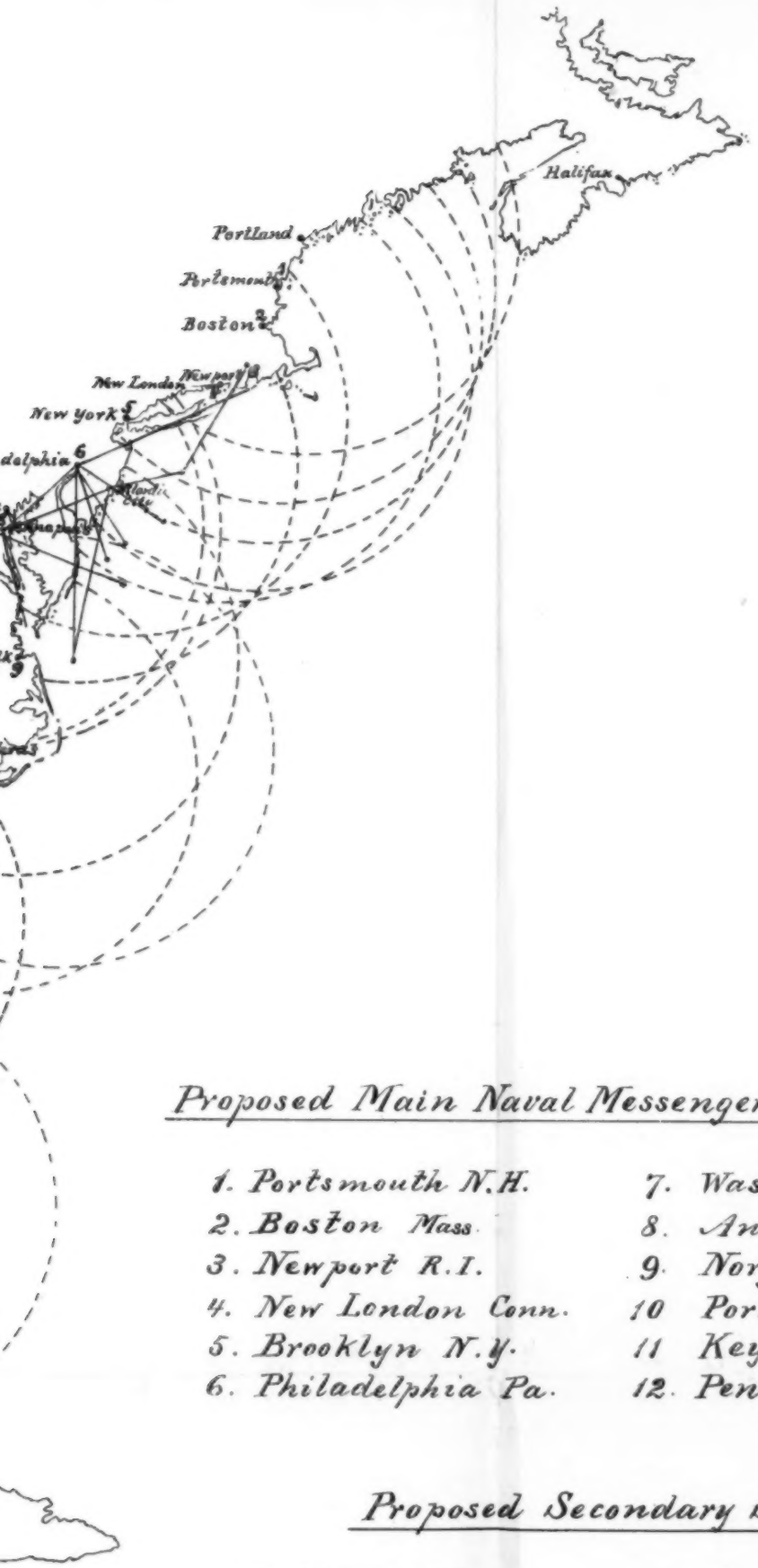
"In peace vessels leaving or approaching the coast could report their own or the position of disabled vessels needing assistance; wrecks, broken machinery, mutinies, lack of food, water (or coal), fire, and thousands of accidents which are likely to happen to any ship at any time, could thus be made quickly known. It would in many instances influence the speculations of merchants, relieve the anxiety of ship owners and the relatives of sailors. They will then have no longer to resort to such uncertain means as signals, meeting of ships, or the floating bottles ashore with messages.

In war they would be of much greater importance. It is essential that the Government should always be able to locate exactly its ships. Great fights seldom occur more than two hundred miles from shore and thus valuable knowledge of skirmishes at sea and the approach of hostile forces and appeals for aid could quickly be communicated."

In order that this service may be successful it must be operated by the Government.

The fact that homing pigeons can fly several hundred miles a day at sea; that they can be bred and trained on board ship in all latitudes and climates; that they can be accustomed to the report of guns; that they can recognize their own ship among others; that they can be relied upon, as proved by numerous experiments, to carry news from the fleet to the shore, and, under favorable circumstances, from the shore to the fleet and from one vessel to another, when beyond the range of signals, should suffice to secure the support of the Government to this new enterprise, and thereby insure the speedy establishment of a permanent system of naval messenger pigeon lofts at the principal navy yards and stations along the Atlantic coast.


------Represent a distance of 240 miles from home loft at the different stations.
——— Lines over which pigeons were flown from the Constellation during past summer, in every case going from sea to shore.
New
Philadelphia
Baltimore
Washington
Norfolk
C. Hatteras
Wilmington
Charleston
Port Royal
Savannah
Pensacola
St. Augustine
Galveston
Tampa
Jupiter Inlet
Key West
CUBA



Proposed Main Naval Messenger Pigeon Stations.

1. Portsmouth N.H.
2. Boston Mass
3. Newport R.I.
4. New London Conn.
5. Brooklyn N.Y.
6. Philadelphia Pa.
7. Washington D.C.
8. Annapolis Md.
9. Norfolk Va.
10. Port Royal S.C.
11. Key West Fla.
12. Pensacola Fla.

Proposed Secondary Stations.

1. Portland Me.
2. C. Hatteras or Wilmington.
3. St Augustine Fla
4. Jupiter Inlet Fla.
5. Tampa Fla.
6. Galveston Tex.

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AMERICAN.

CASSIER'S MAGAZINE.

VOLUME II., No. 6. Electrical equipment of modern ships. Engine testing. Transmission of power. Steam and pressure gauges. Tandem compound engines.

No. 7. A test of multi-cylinder engines. The value of water power. Utilizing the power of ocean waves. Steam distribution in single-acting compound engines.

No. 8. Progress in generating high pressure steam. Direct connected engines. Compressed air. The measurement of power. A new independent condenser.

No. 9. Shipbuilding in America. Machine molding. Electrical equipments of modern war ships. Modern methods of storing coal.

No. 10. Steam and electric power. Direct connected engines. Mechanical methods of securing dry steam. Compound engine, with Proell's valve gear. Brayton petroleum engine. New machine tools. J. K. B.

IRON AGE.

MAY 5, 1892. The manufacture of gun-cotton.

Description of the method employed at the U. S. Torpedo Station.

MAY 12. Balancing marine engines.

Paper read by A. F. Yarrow before the Institution of Naval Architects.

The submarine sentry.

Device for automatically indicating when a certain minimum depth has been reached.

MAY 19. Report of meeting of American Society of Mechanical Engineers.

Synopsis of papers and discussions. Among the papers is one upon the utilization of the power of ocean waves by Naval Constructor A. W. Stahl, U. S. N.

The Seller's turning and boring lathe for 16-inch B. L. R.

Description, with plates, of the machine made for the Washington navy yard.

MAY 26. United States ferry boat.

Description and drawings of the ferry boat for the navy yard, Portsmouth, N. H., particularly of the Towne boiler.

Attaching sea valves to hulls of double-bottom ships. Electric forging and tempering.

Drawings and description of apparatus.

Making projectiles for the Government.

Machinery and methods employed by the U. S. Projectile Co., of Brooklyn, N. Y.

JUNE 2. Japanese war vessels.

New additions to the Japanese navy.

JUNE 9. Breech mechanism for heavy guns.

Drawings and description of the breech mechanism of the 10″ and 12″ navy B. L. R.

Submarine torpedo-boats.

General account of results accomplished and description of the Baker boat, tested at Detroit, Mich.

JUNE 16. Recent development and progress of gun manufacturing in the United States; I., by W. H. Jaques, late U. S. N. The Mosher steam boiler.

Description and plates of a boiler designed for small vessels of high speed.

JUNE 23. Recent development and progress of gun manufacturing in the United States; II., by W. H. Jaques, late U. S. N. Microscopic structure of iron and steel, by P. Kreuzpointner (illustrated).

JULY 21. Firing the Justin projectile.

Experiments with projectiles loaded with explosive gelatine in shell guns.

AUGUST 18. Seabury's breech mechanism for rapid fire artillery.

Description of mechanism patented by Lieut. Seabury, U. S. N.

Fellows steam steering gear.

SEPTEMBER 1. Making great guns; shrinking on jackets and hoops.

Description of manufacture of 10″ rifle at the Watervliet Arsenal.

OCTOBER 6. Test of an Ellis-Tresidder compound armor plate at Shoeburyness.

OCTOBER 20. Electric motors in a machine shop. The Brown segmental wire gun.

Synopsis of paper read at the meeting of the American Institute of Mining Engineers, by N. B. Whitman.

OCTOBER 27. Random shop notes.

Method of removing hoop from built-up gun which had cooled before properly placed, by means of making a casting of iron around the exterior of the hoop and thereby expanding it.

NOVEMBER 3. Tool for boring breech-loading ordnance.

C. M. K.

JOURNAL OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS.

VOLUME IV., No. 1. The U. S. S. S. Cushing and its experiments investigated. A study of the elements of a screw propeller. The failure of steel castings for U. S. steamship Maine and Cruiser No. 11. Bilge drainage. Notes: The Atlantic liners; D'Allest boilers; Defective boilers in English war vessels; Coal consumption in men-of-war; Basic Bessemer steel; Inspection of machinery afloat in British navy; Ships under construction at home and abroad.

No. 2. Screw propellers of U. S. naval vessels. Method of moulding a cylinder at the Bath Iron Works. Transmission and distribution of power on modern ships. Electric pumping plant for salt water aquaria. Columbian Exposition. Proposed revision of rules of Steamboat Inspection Service. Balancing marine engines. Notes: Smoke; Navy boilers; Effect of depth of water on speed of ships; Serve boiler tube; Triple screws.

No. 3. The chase of the Itata. Moulding and casting the cylinders of the Raleigh and Cincinnati at Brooklyn navy yard. Feed water heating. Comparison of the propellers of some U. S. navy ships. Proportioning riveted joints for boilers. Trial of the Ville de Douvres. Experiments with basic steel. Whaleback steamers. Notes: French naval contracts; Iron vs. steel boiler tubes; Normand's tubular boiler; Leaky boiler tubes; Harvey carbonizing process.

J. K. B.

JOURNAL OF THE MILITARY SERVICE INSTITUTION.

JULY, 1892. Smokeless powders. Prussian great general staff. Practical drill for infantry. Practical workings of rifle practice against an enemy.

The author dwells at some length on the evidently bad position of aim as laid down in the new Drill Book, that of the army being identical with the navy.

Civil war in Chile.

SEPTEMBER. Is the tendency of modern drill regulations salutary? The value of manœuvres and Kriegs-spiel. The physical training of the enlisted man.

NOVEMBER. Guns and forts. Our new infantry drill regulations.

F. J. H.

JOURNAL OF THE UNITED STATES ARTILLERY.

JANUARY, 1892.

The first number of this Journal is temporarily edited by First Lieutenant W. B. Homer, First Lieutenant H. C. Davis, First Lieutenant J. W Ruckman, First Lieutenant C. DeW. Willcox, and Second Lieutenant L. G. Berry, all of the U. S. Artillery. The Journal will be published quarterly by the Artillery School Press, of Fort Monroe, Virginia.

The effect of wind on the motion of a projectile.

A mathematical deduction of the deflections, retardations and accelerations given to a projectile by the influence of the wind, including formulæ and tables, showing method for calculation of such deflections.

The determination of the velocities of projectiles by means of sound phenomena (continued). Our artillery organization. Range tables for the 12-in cast iron B. L. mortar. The Chilian navy.

APRIL. Sea coast guns and steel armor.

After thoroughly discussing the probable conditions that would exist in the event of a fort being attacked by iron-clads, the author arrives at the conclusions that the largest gun thus far designed, the XVI.-in. B. L. R., will be too small to penetrate the heaviest armor of the heaviest battle-ships; that the VIII.-in. B. L. R. should be lengthened to 50 calibres in order to pierce the light side armor of iron-clads, and that the X.-in. and XII.-in. B. L. R. can be used against the light side armor. The minimum range used is 4000 yards, and it seems unfortunate that the discussion was not brought to 1500 yards, which in all probability would be somewhat nearer the range the battle-ship would seek, especially if the motion of the ship was sufficiently great to make it necessary to come close in order to get a steadier platform, and to insure greater accuracy.

Notes on field practice. Notes on the English proving ground at Shoeburyness. The determination of the velocities of projectiles by means of sound phenomena (concluded).

JULY. Theoretical instruction of gunners.

A detailed system of daily instruction for enlisted men and non-commissioned officers, covering the ground necessary that they become thoroughly proficient in the handling of ballistic formulæ. As an illustration of the necessity of such knowledge an example of a four-gun battery being attacked by a squadron. The captain desires certain information, and after finding the range, by means of a range finder, asks of his first sergeant: "What is the normal elevation for that range?" The sergeant *calculates* or consults a table previously calculated, etc.

If the sergeant has a range-table it requires no knowledge of ballistic formulæ to be able to run down the table to the range, and abreast of it find the angle of elevation. If the captain is going to stop to have the range calculated, applying the barometer and thermometer, the ship will be nowhere near where it was when the range was first given by the time the calculation is finished. Knowledge of the use of ballistic formulæ might be desirable, but hardly essential to the proper performance of the gunner's duties.

A study of the effects of smokeless powder in a 57 mm. gun. Department of Chemistry and Explosives of the U. S. Artillery School. The effect of accelerating and retarding winds upon projectiles. A proposed design for a new ballistic target.

OCTOBER. Electricity and the art of war. Recoil of heavy guns and its control. Time fuse with Shrapnel fire. F. J. H.

JOURNAL OF THE UNITED STATES CAVALRY ASSOCIATION.

JUNE, 1892. Snap shooting with the rifle and pistol. Gymnasiums and riding halls at cavalry posts. F. J. H.

ORIGINAL PAPERS ON DYNAMO MACHINERY AND ALLIED SUBJECTS. By John Hopkinson, M. A., D. Sc., F. R. S. New York: The W. J. Johnston Co., 1893. 249 pages. Price, $1.00.

The collection in one volume of all of Dr. Hopkinson's excellent papers on electro-technical subjects will be highly appreciated by electrical engineers and others interested in the theory and use of dynamo-electric machinery.

The first three papers are on electric lighting; the fourth and fifth upon the theory and design of continuous-current dynamos. In these five papers the characteristic curves of dynamos and efficiency experiments are ably discussed.

There are also five interesting papers on alternating currents and converters.

Recent graduates of the Naval Academy will find this book interesting and profitable. N. M. T.

RAILROAD AND ENGINEERING JOURNAL.

JULY, 1892. The cruiser Chicago. Columbian exposition notes. A process for wood preservation. A light-draft stern-wheel steamboat. Two-cylinder versus multi-cylinder engines. Aluminum and its uses. The Almy tubulous boiler. Steel stern-frame casting for the Marblehead. The Baker submarine boat.

SEPTEMBER. The Watervliet gunshop. Electric safety signals. The battle-ship Royal Sovereign. The future developments of electric railroads. The Nicaragua Canal. U. S. naval progress. Columbian Exposition notes.

OCTOBER. The Krag-Jorgensen repeating rifle. The Belpaire boiler. An oil-burning furnace. The battle-ship Barfleur. U. S. naval progress. J. K. B.

TRANSACTIONS OF THE AMERICAN SOCIETY OF MINING ENGINEERS.

VOLUME XX. The alluvial tin deposits of Siak, Sumatra. Explosions from unknown causes. Chinese silver mining in Mongolia. A compound plunger hydraulic pump. Sampling ores without use of machinery. The first American blast furnace. The physical and chemical equations of the open-hearth process. Aluminium in steel ingots. International standards for the analysis of iron and steel. Electricity in welding and metal working. American blast furnace practice. Manganese in cast iron. Apparatus for the manipulation of iron and steel plates during the process of finishing. The handling of ingots and moulds in Bessemer works. Electric loco-

motives in German mines. The fuel supply of the United States. Results of stream measurement of U. S. Geological Survey. Notes on sampling iron ores. The utilization of anthracite waste.

J. K. B.

FOREIGN.

ALLOYS OF IRON AND CHROMIUM. By R. A. Hadfield. Reprint from the Proceedings of the Iron and Steel Institute, received by the Naval Institute through the courtesy of Captain E. L. Zalinski, U. S. A., Associate Member.

The recent remarkable development of the steel industry of the United States in its application to warlike material—a development which has been effected largely by study of special alloys of iron in which the action of carbon is modified by the presence of other substances—gives to this paper by Mr. Hadfield a peculiar timeliness. The striking improvement in armor, due to the addition of a small percentage of nickel, has been paralleled by an almost equally striking improvement in projectiles, resulting from the use of manganese and chromium. Chrome steel, which is now used by most of the leading firms of the world for armor-piercing projectiles, was, as Mr. Hadfield is careful to acknowledge, first manufactured on a practical scale in this country, the present Chrome Steel Company, of Brooklyn, being the pioneers in its development. Its first application for armor-piercing projectiles was in the case of a 6-inch shell manufactured and tested, with remarkable results for that period, at the Naval Ordnance Proving Ground at Annapolis, by the recent chief of the Naval Bureau of Ordnance.

The celebrated Holtzer projectiles owe their excellence, at least in part, to the use of this alloy, to which also Mr. Hadfield attributes much of the important success which his firm has recently had in producing high-grade projectiles for the English government. Photographs accompanying the present paper show very strikingly the extent of this success, and leave no room for doubt that chromium is an important factor in the manufacture of steel for purposes where it is important to secure a high tensile strength and elastic limit and great hardness without the sacrifice of elongation, at the expense of which these qualities are usually obtained.

Mr. Hadfield's experiments make it clear that chromium, *per se*, does not give hardness, nor does it in any other manner take the place of carbon. Its function, like that of silicon, manganese, aluminum and nickel, in the cases where these are alloyed with iron and carbon, is to *assist* the carbon, not to replace it.

It appears clearly, also, that the value of the chromium depends greatly upon the percentage of carbon present, the effect of its addition to low steels being hardly perceptible.

With regard to the nature of its beneficial effects upon high steels, the author does not speak with much confidence. He considers, however, that it certainly assists the hardening action of the carbon in tempering, and that, to some extent, it plays the part of a hardener without the interposition of a cooling medium. The paper gives interesting details of the history of the metal chromium since its discovery at the end of the last century, and of the process of combining it with steel. A. M. K.

ALMANACH DER KRIEGSFLOTTEN.

PART I., 1892. Tables of weights and measures, and reduction tables for the English and metric systems.

PART II. Armament of the different fleets.

Tables of 1891 revised and based upon the latest data.

PART III. List of vessels of the world.

Giving dimensions, horse-power, armor, armament, speed, material and date of launching. Also one hundred and forty-three cuts of armored ships, with alphabetical list of same.

The Austrian navy in the East Indies.

An account of the extended cruises of the Austrian men-of-war Nautilus and Aurora, in the East Indies, from 1884–1888, based upon the reports of the commanders of these vessels, supplemented by consular and other authentic reports, by Commander V. Benko. H. O.

ANNALEN DER HYDROGRAPHIE UND MARITIMEN METEOROLOGIE.

XXTH ANNUAL SERIES, VOLUME I. Report on the tests of running lights on board ship, by Prof. Dr. Seaward Weber, of Kiel. Deep sea soundings in the Indian Ocean. The Argentine territory in Terra del Fuego. Remarks on the harbor of Constitution, Chile, by Captain Rötger, of the German navy. Remarks on the sailing directions of the harbor of Mollendo, Peru, by Commander Kirchoff, of the German navy. Remarks on the islands Anno Born, Banana and Mossamedes, west coast of Africa, by Commander v. Dresky, of the German navy. Report of Captain I. G. Nichelson, of the German bark Theodore; voyage from Liverpool to Callao; Callao harbor; route from Callao to the northern ports of Chile; voyage from Iqueque to Falmouth. Observations on the harbors of Corinto and Venadillo, west coast of Nicaragua, by Captain Rikert, of the German bark Caroline Behn. The chart of magnetic declinations, by Prof. Dr. G. Neumayer, of Hamburg. Minor notices: The passage of the German ship Urania, Captain Gahde, through the Straits Le Maire, en route from New Castle to Valparaiso; Sudden changes in the temperature and weather off Cape Guardafui, east coast of Africa; On the driving ashore of sea birds in storms; Tables.

VOLUME II. Remarkable storms; the storms of November 11th and December 11th, 1891, and those from the 5th to the 7th of January, 1892, by Prof. W. J. Van Bibber. The difference of temperatures of air and water in the China Sea and adjacent waters, by Captain G. H. Seemann. Remarks on Batonga, Gaborn, Anno Born and St. Thomé, by Lieutenant Commanding Goecke, commanding the German gunboat Hyäne. The use of oil to quiet the sea. Guayaquil and Callao; extracts from the cruising report of Captain C. Oltman, of the German bark Pacific. Voyage from the Straits of Sunda to Singapore, thence to Pulo Penang; extracts from the report of Captain C. Sauder, of the German bark Standard. The comparison of Beaufort's scale with the velocity of the wind. Minor notices: Rat Island, Houtman Abrolhos, west Australia; The pilot system of Townsville, Queensland; peculiar cloud formation experienced by the steamer Sophie Rickmers, in the bay of

Bengal; the charges of the Newcastle Tugboat Company between Sydney and Newcastle, N. S. W.; The weather on the German coast in January, 1892; Tables.

VOLUME III. A new method of finding longitude by star observations, by H. Florian, of Vienna. A study of fog-signals, by Prof. Dr. Mohn, of Christiania. Remarks on the harbor of Chang Tau, Chusau Islands, from a report of Lieutenant Commanding Muller, of the German gunboat Iltis. Hydrographic observations on the Gulf of Guinea, from a report of Lieutenant Commanding Goecke, of the German gunboat Hyäne. Report on Callao, Corinto and La Union, by Captain Green, of the German bark Elizabeth. Report on Guaymas, Santa Rosalia and Cape Horn, by Captain Burmester, of the German bark Guaymas. Report of Captain A. Schulz, of the German bark Julio Theodoro. The use of oil to quiet the sea. Bottle-post; records of bottles thrown overboard and picked up. Minor notes: Correct longitude of Suez; The hurricane of August, 1801, at Martinique; New nautical and hydrographic publications; Weather on the German coast in February, 1892; Tables.

VOLUME IV. A study of fog-signals, by Prof. Dr. Mohn, Christiania (conclusion). Report on the determination of the length of the simple seconds pendulum and specific gravity constants at Hamburg, by A. Mohlke. On the appearance of electrical phenomena around Cape Horn, between 50°–60° S. lat. and 90°–80° W. long., by Captain H. Haltermann. Voyage of the German frigate Leipsic, Captain Rötger, from Valparaiso to Montevideo. Voyage of the German man-of-war Moltke, Captain v. Erhardt, from Bahia to Port Spain, Trinidad. Report of Captain Haase, of the German ship Kepler, on harbor of Chittagong. Voyage of the German ship Kaiser, Captain R. Alberts, from Singapore to Besuki and Pasumau. Voyages of the German ships Adolph, Captain Westergaard, and Gustav and Oscar, Captain Seemann, from Hong Kong to and through the Straits of Sunda, Esmeraldas, Ecuador. Report of Captain Dreyer, of the German schooner Neptune. Minor notes: Weather on the German coast in March, 1892; Tables.

SUPPLEMENT. A method to calculate the time of high and low water at any place, by Prof. C. Börgen.

VOLUME V. Report of the German naval observatory on the results of magnetic observations on the coast of Germany in 1891. Magnetic observations on the coast of the Adriatic in 1889, 1890, by direction of the Marine Department of Ministry of War, of Austria. Contributions to the knowledge of the wind and weather in the vicinity of Cape Horn, from observations between 1882–1891, by Captain H. H. Haltermann, assistant in the Naval Observatory. Report of Captain Köller, of the German bark Freya, on Guayaquil, Esmeraldas and Manta. Report of Captain Kuhfal on the harbor of

Mayaguez, Porto Rico, and the hurricane of September 19 and 20, 1891. Minor notes: Ice in the vicinity of Cape Horn; Red color of the sea and the whales of the Indian Ocean; The weather on the German coast in April, 1892; Tables.

VOLUME VI. Remarks on the great circle sailing charts on gnomonic projection, recently issued by the U. S. Hydrographic Office, by Dr. Meyer, Professor in the University of Kiel. Contributions to the knowledge of the wind and weather in the vicinity of Cape Horn (continuation). Roth Island: SW. coast of Timor I. The Mauritius hurricane of April 29, 1892. Hydrographic information in regard to several ports on the west coast of South Africa; also in regard to currents experienced on the passage from Cape Town to the Cameroon, by the German gunboat Hyäne, Lieutenant Commanding Platche. Information in regard to the harbor of La Guayra, and the approach to Aux Cayes, Hayti, from the report of Captain Erhardt, of the German man-of-war Moltke. Voyage from Apia to the Gilbert and Marshall Islands, from the report of Commander Fischer, of the German cruiser Sperber. Sailing along the coast of Ecuador, from the report of Captain Frerichs, of the ship Aeolus. Weather on the German coast in May, 1892, with tables. A chart of the drift ice off the coast of Newfoundland, from the middle of February to the early part of June, 1892.

VOLUME VII. Drift ice in southern latitudes, from December, 1891, to May, 1892. Conclusion of contributions to a knowledge of the wind and weather around Cape Horn, etc. Report on the fifteenth competitive test of marine chronometers in the winter 1891–92, made at the Naval Observatory at Hamburg. Voyage of the German man-of-war Leipsic, Captain Rötger, from Cape Town to Zanzibar via Port Elizabeth, Delagoa Bay, Mozambique, Luidi, Kilwa Kiwinji and Dar es Salam. Report on the sailing directions for, and the bouyage in the channel of, the harbor of Mozambique, by Captain Frantzius, of the German navy. Remarks on the sailing directions for, and on the harbor of, English River, Delagoa Bay, by Commander Kirschoff, of the German navy. Sailing directions for Wentchau, by Lieutenant Commander Muller, commanding German gunboat Iltis. Hydrographic notes on the west coast of South Africa, by Commander Hessner, of the German navy. Currents between Camaroon and Loando, west coast of Africa, from the report of Commander Goecke, of the German navy. Minor notes: Peculiar thunder-storm experienced by the German steamer Flandria, Captain Hahn, on the voyage from St. Thomas to Hamburg; Illuminated clouds observed by Captain Kühlewein, of the German steamer Albingia, on the voyage from St. Thomas to Havre; The weather on the coast of Germany in June, 1892; Tables; A chart of the approach to Wentchau.

VOLUME VIII. Description of an apparatus to determine the

error of the sextant due to eccentricity, by C. Koldewey, of the German Admiralty. The Samoan hurricanes of February and March, 1889, with five charts and one diagram, by E. Knipping, formerly Director of the Observatory of Tokio. The tracks of hurricanes in the South Indian Ocean. The submarine sentry, a sounding machine, invented by Samuel H. James, to indicate the depth of water at any moment without delaying the vessel. Voyage from Newcastle, N. S. W., to Mazatlan, and thence to Salina Cruz and neighboring ports, from the report of Captain Blanke, of the German bark Marseille. Somabaya, passing through Torres Straits to the westward, from the report of Captain Hendorff, of the German bark Werner. Drift ice in the South Atlantic Ocean. Sailing directions for the Indian Ocean issued by the German Naval Observatory. Minor notes: Meteors; Time signal at Lussinpiccolo; Waterspout experienced by the German ship Columbus, Captain Sauermilch, on the voyage from Cardiff to Singapore; The weather on the coast of Germany in July, 1892; Tables. H. O.

BOLETÍN DEL CENTRO NAVAL.

FEBRUARY, 1892. Trials of the Canet gun of 32 cm., 40 caliber, mounted in barbette towers. The coasts of Patagonia.

MARCH–APRIL. Specialties in the navy; mode of recruitment. Modern constructions; plans of a rapid cruiser for the Centro naval. The Montes' artificial horizon. Report of the Board appointed to prepare a new plan of organization and course of studies for the naval school.

MAY. A voyage to Tierra del Fuego, related by Commander O'Connor. J. L.

DEUTSCHE HEERES-ZEITUNG.

MAY 7, 1892. The past and present character of small-arm targets.

MAY 11. French fortifications.

MAY 14. The progress of the German field-telegraph system. The question of cavalry-fire in Russia.

MAY 18. The military organization of the Russian railroad service during peace.

MAY 21. March of an army corps.

MAY 25. The fifth international conference of the Order of the Red Cross.

MAY 28. The military bicycle service of France.

JUNE 1. Targets for battle practice in the German army. Remarks on types of modern war-ships. Distribution of naval forces in European waters.

JUNE 4. The new regulations for infantry-fire of the Italian army. Distribution of the naval forces in European waters (continuation).

JUNE 11. The colonial military force of Holland. Distribution of the naval forces in European waters.

JUNE 18. The officers of the Turkish army.

JUNE 22. The tests of the 12 cm. of 40 calibers, and the 15 cm. of 15 calibers, Krupp rapid-firing guns. The coast defences of France.

JUNE 25. The attack and defence of modern armored fortifications.

JUNE 29. The attack and defence of armored fortifications (conclusion).

JULY 2. The term of service of the French army. The Italian mountain troops.

JULY 6. The English and Russian military strength in Asia. The Italian mountain troops (conclusion).

JULY 9. The Chinese army.

JULY 13. The small caliber rifle in the civil war in Chile, 1891.

JULY 16. The field-gun of the future and the criticism of the present. Military balloon service.

JULY 20. Military balloon service (continuation).

JULY 23. The warrant for a one-year volunteer service. Military balloon service (conclusion).

JULY 30. The German military train.

AUGUST 10. The training of the infantry recruits of the German army. The French manœuvres for 1892.

AUGUST 17. The question of target or field practice. Changes in the battle tactics of infantry due to the introduction of small-caliber rifles and smokeless powder.

AUGUST 24. Dried vegetables and corn coffee as provisions for an army. The French manœuvres, 1892. The reorganization of the Bulgarian army. What practical lessons have we for a naval battle at the end of the 19th century?

AUGUST 31. The French manœuvres of 1892. What practical lessons have we for a naval battle at the end of the 19th century (continuation)?

SEPTEMBER 7. Krupp and Canet. Change in the character of the British war-ships on foreign stations between July, 1891 and 1892. What practical lessons have we for a naval battle at the end of the 19th century (continuation)?

SEPTEMBER 14. What practical lessons have we for a naval battle at the end of the 19th century (conclusion)?

SEPTEMBER 21. The two-years term of service a necessary consequence of universal military duty. The storming of Ismail on Dec. 22, 1790.

SEPTEMBER 24. The French manœuvres of 1892. The storming of Ismail on Dec. 22, 1790 (continuation).

SEPTEMBER 28. A criticism of the new pontoon-service regulations of the German army. The storming of Ismail (conclusion).

H. O.

JOURNAL OF THE ROYAL UNITED SERVICE INSTITUTION.

VOLUME XXXVI., No. 171, MAY, 1892. Pigeons for land and sea service.

A paper of interest in view of recent experiments on the Constellation during the past summer, and in connection with the papers by Lieutenant Niblack and Prof. Marion in this issue of the PROCEEDINGS.

Atlantic weather and its connections with British weather. The Royal Naval Exhibition of 1891. The defensive strength of Russia. The naval schools of the chief continental powers (continued).

No. 172, JUNE. Military geography.

A short but interesting article on the broad principles of the subject, illustrated by references to the frontier defenses of European countries as affected thereby.

Electricity as applied to torpedo and other naval purposes. Military education. The place and uses of torpedo-boats in war.

This paper is by Mr. Laird-Clowes, and is essentially the prize essay of the U. S. Naval Institute for the current year. It is quite fully discussed by a number of officers of experience in the handling and management of torpedo-boats. The discussion develops many points in which the practical men take issue with the lecturer, and the whole is worth serious study by our own officers, who have practically nothing of personal experience to aid them in forming their opinions on this important subject.

Professor Frölich's new method for determining the velocity of a projectile in the gun (trans.). The naval schools of the chief continental powers (concluded).

No. 173, JULY. Modern aërial navigation.

This very interesting lecture, by Captain Fullerton, R. E., is written from the standpoint of the modern scientific inquirer, and presents the latest ideas on the subject. The possible military changes that would result from success in this line are briefly touched upon, but the lecturer leaves the reader to judge for himself of the practicability of any or all of the systems of flight mentioned.

Discussion on the subject of the naval prize essays. Combined tactics. Précis of the instructions for gunnery and torpedo schools-ships of the Italian navy.

No. 174, AUGUST. Ambulance work and matériel in peace and war. The dimensions of modern war ships.

In this lecture Captain Eardley-Wilmot advocates battleships of moderate displacement, from 9000 to 10,500 tons, to form the bulk of the fleet. He thinks it practicable, in view of recent improvements in armor, to limit its thickness to 12 inches; the speed of battle ships need not be very great, but the coal capacity should be, and the torpedo equipments very complete. In arguing for moderate, as against great displacement, he considers the time and and cost of construction, the lighter draught and greater docking facilities, the influence of the ram and torpedo, and the strategical advantages of being able to cover a wider extent of sea or coast, and of being able to detach small squadrons without unduly weakening the main body. For cruisers, he considers the proper size about 4000 tons, is opposed to any considerable weight of armor, is in favor of a not too heavy armament. He argues that the heavy gun, if permissible at all, should be a stern, not a bow chaser, and insists on a great coal endurance as a vital point.

Experiments at Spandau to illustrate the penetration of German rifles (trans.).

A contribution to the literature of the effect of modern high-power, small calibre rifles.

No. 175, SEPTEMBER. Magazine rifles.

Captain James, in this very interesting paper, lays down the six principles upon which the ideal rifle should be constructed, as follows:

1. The bolt should have a rectilinear motion, because that enables the soldier to fire without taking the rifle from the shoulder.
2. The magazine should be central, and should hold ten or twelve cartridges.
3. The cartridges should be contained in a frame, or filler, so that they can be rapidly loaded into the magazine.
4. The cartridges should be easily taken from the holder for use in the weapon as a single loader.
5. There should be a cut-off, which should be so arranged as to facilitate the use of the weapon as a single loader.
6. The bore should be sufficiently small to enable a long bullet to be driven at a high velocity, so that at medium ranges, *i. e.*, within 800 yards, one sight will suffice for military purposes.

Captain James argues in favor of these several points, and continues with a discussion of the various weapons forming the armament of the different European powers. He then discusses (*a*) the effects produced by the modern military rifle upon troop formations, and (*b*) the physical effects of the bullets on the human frame, and concludes with a series of tables showing the present armament of European armies, latest pattern magazine rifles, the penetration of modern rifles, and a list of foreign surgical works dealingwith the effects of small bore rifles upon the human frame.

Torpedo net defenses (trans.).

A very good argument against the use of nets in any case. "In our opinion the torpedo catchers and torpedo-boats are, as yet, the best means of protection against the insidious attacks of their companions."

No. 176, OCTOBER. Colonel von Löbell's Annual Report upon the changes and and progress in military matters in 1891. The French naval manœuvres. The field-gun of the future. H. S. K.

MILITAR WOCHENBLATT.

MAY 11, 1892. Krupp rapid-fire guns.

A brief description of the guns of larger calibre, those of 12, 15 and 16 c. m., with a comparison table of these guns with those of Armstrong, Hotchkiss and Canet.

Manual of the organization of the French army.

A brief review of the book.

MAY 21. The fortifications of Constantinople.

JUNE 1. A review of the latest discoveries and inventions in the military and technical fields. The Danish navy.

JUNE 4. A contribution to the study of field-guns of the future, and especially of a rapid-firing gun.

JUNE 8. Tests of hard bread in France.

JUNE 11. Review of the latest discoveries and inventions in the military and technical fields (conclusion).

JUNE 18. The new Belgian infantry rifle. The improved Mauser gun adopted for the Belgian infantry.

JUNE 25. The English battleship Royal Sovereign.

JULY 2. The Sims-Edison torpedo (from the Engineer).

JULY 9. Remarks on the use of the sword and fire-arms in the War of Secession in the United States, 1861–65. The raising of a sunken coal steamer. A short account of the raising of coal steamer in Wurla Roads, Gulf of Smyrna, by the crew and with the appliances of H. M. S. Edinburgh.

JULY 30. Submarine guns in the United States.

AUGUST 10. The training of infantry in fire practice.

AUGUST 13. The new Mauser repeating rifle for Turkey, Argentine and Spain.

SEPTEMBER 3. Armor tests in the United States. The naval policy of the United States.

SEPTEMBER 24. The wound of the Mannlicher rifle. Attack on coast defenses.

SUPPLEMENT.

No. 2, 1892. The winter campaign of 1807 in Prussia, by Captain Grauert, of the German general staff. Blücher's campaign against Lübeck in 1806, by Major Beseler, of the German general staff.

No. 3. The British naval manœuvres in 1891, by Captain Stenzel, of the German navy. The conscription under Napoleon I., by Col. von Lettow-Borbeck, of the German army.

No. 4. The study of the wars of Frederick the Great in their relation to the modern art of war, by Major F. von Bernhardt, of the German general staff.

No. 5. Military events of the civil war in Chili in 1891, by Captain Schaumann, of the German army. The training of cavalry for reconnaissance service.

Nos. 6 and 7. The service of the 5th Cavalry Division of the German army in the days between the 10th and 16th of August, 1870. H. O.

MITTHEILUNGEN AUS DEM GEBIETE DES SEEWESENS.

VOLUME XX., No. 1. The reorganization of the Austrian-Lloyd S.S. Co. The development of the torpedo-boat; translation of the article on the subject by Lieutenant R. Hunt, U. S. N., begun in Naval Progress, 1801. Rapid-firing guns of large calibre (continuation). The guns manufactured by the Société Anonyme des Forges et Chantiers de la Méditerranée. Tests of armor plates in England and North America; an account of the tests of plates treated by the Tressider process and of those by the Harvey process. The high-speed gunboat built for Costa Rica by Yarrow & Co. The new English auxiliary cruiser Ophir. Nickel steel for shipbuilding. The Brazilian torpedo-boats Marcilio, Dias, Ignatemy and Araguay. Petroleum as fuel. Rust protection for iron and steel wire. A new paint. Captain Garciuts' method of using oil at sea.

Nos. 4 and 5. The belligerents' rights on the sea in the Chilian Civil War of 1891. Continuation of article on rapid-firing guns of large calibre—guns manufactured at the Krupp establishment The system of coast defence in European countries, by Lieutenant C. C. Rogers, U. S. N. The English naval budget for 1892–93. The attack of coast defences by a naval force, by Captain H. J. May, of the English navy. The telegraphic machine for ships of V. Schuckert & Co., of Nuremberg. The use of aluminium in the construction of yachts. The budget of the German navy 1892–93, and the fleet neceessary for service in 1892–93. The new French torpedo-boats Eclair, Orage and Kahyle. The French torpedo-cruisers of the Bomb class. The American monitor Miantonomoh. The trial of a special Chamon armor plate. The endurance of English guns of large calibre. Ballistics of smokeless powder, manufactured by Krupp. Trials of submarine guns in Italy. The English torpedo-boat Vulcan. The Italian torpedo-cruiser Urania. Bohmayer's electric gong. The union of the Caspian and Black seas by canal. Trials of anchors at Portsmouth, England. The use of carrier pigeons at sea. Franklin's life buoy. The trials of the Sims-Edison torpedo in the United States. The Sims-Edison electric life-boat.

Nos. 6 and 7. A new coast chart of the Adriatic, by Lieutenants Duger and Nappes of the Austrian navy. Probable influence of rapid-firing guns upon naval tactics and shipbuilding, by Rear Admiral Long, of the English navy. The system of coast defences of Europe, by Lieutenant C. C. Rogers (conclusion). The use of liquid fuel on board men-of-war, by George Herbert Little. Remarks on manageable torpedoes. The vibration of ships and the use of balanced machinery. The budget of the Italian navy, 1892–93. Comparison of the ballistic data of the 10, 12 and 14 c. m. Spanish rapid-firing guns, with the guns of Armstrong, Krupp, Hotchkiss and Canet, of the same calibre. In the military top of a modern battleship or cruiser. The Italian battleship Sardigna. The launching of the French battleships Bouvines and Jemmapes. The new French battleship Massena, building at the works of the Société des Chantiers de la Loire. Launching of the English cruiser Crescent. The use of cellulose in the U. S. navy. The establishment of a training-ship to qualify men in the use of rapid-firing guns. The effect of lightning on board ship, and the use of conductors. Liquid fuel for torpedo-boats. Budget of the Russian navy, 1892. The manufacture of cordite. A submarine boat for diving purposes. The Italian torpedo-cruiser Urania; a description of the vessel. The submarine gun in America. A floating net to quiet the sea, invented by Baron d'Alessandro; trial of the same in France. The submarine boat of George C. Baker. The English battleship Royal Sovereign.

Nos. 8 and 9. The methods of the so-called new nautical astronomy, in its historical development and with regard to its practical applicability. Rapid-firing guns of large calibre—the guns manufactured by the Maxim-Nordenfelt Gun and Amunition Co., Limited (continuation). Budget of the French navy, 1893. A new Normand torpedo-boat. Regulations of the French navy for the preservation of boilers. The accident to the boilers of the French armored cruiser Dupuy de Lôme. The introduction of steel wire hawsers in the French navy. The launching of the German dispatch-boat, Hohenzollern. New vessels for the Argentine navy. The U. S. gunboat Castine. Pilots for torpedo-boat service in the French navy. The Siamese yacht and cruiser Maba Chackrkri. The whaleback steamer Charles W. Wetmore. Description of the submarine boat of George C. Baker. A miss-fire of an automobile torpedo; showing the danger of these weapons and the necessity of care in the use of them. The trials of short launching-tubes for torpedo. New warships for Brazil, building at the Armstrong works at Newcastle. Trial of the battery of the English turret-ship Abyssinia. 1000 m. initial velocity obtained with Canet 57 m. m. The Grenfell illuminated sights for great guns; trial of the same in England. The trials of the heavy guns of the French battleship Neptune.

SUPPLEMENT.

Report of magnetic observations on the coast of the Adriatic, made by direction of the Marine Department of the Ministry of war of Austria, conducted by Commander Franz Laschober, assisted by Lieutenant Kesslitz, of the Austrian navy. A text-book on electricity for non-commissioned officers, especially as applied to use on board of warships, by M. Burstyn, marine and electrical engineer.

H. O.

PROCEEDINGS OF THE INSTITUTION OF MECHANICAL ENGINEERS.

FEBRUARY, 1892. Notes on the mechanical features of the Liverpool water works. On the disposal and utilization of blast furnace slag.

MAY. Report upon the trial of the Ville de Douvres.

Since their last report the Research Committee on marine engine trials have been enabled to carry out a trial on a large paddle steamer, the Ville de Douvres. A full description of the trial is given with the results, to which is appended the tabulated data showing the comparative results of the trials of the five screw steamers previously tested.

On condensation in steam engine cylinders during admission.

In this paper the author gives the results of some experiments on the steam engine with the object of determining the amount of loss by condensation in the cylinder as distinguished from the liquefaction necessarily caused by the performance of work, and embodying them in the shape of approximate formulæ for determining the condensation under given conditions.

J. K. B.

PROCEEDINGS OF THE ROYAL ARTILLERY INSTITUTION.

JUNE, 1892. Notes on applied field fortification.

Some useful hints in regard to the selection of position according to the nature of the ground; the disposition of general and battalion officers, and of the different lines of troops; and the methods of defense and precautions to be taken to prevent night attacks.

Notes of lectures on artillery in coast defence. Fire tactics.

This chapter on fire tactics embraces eight general rules for the character of the fire to be used in forts against armored vessels, and is preceded by general remarks on the character of the different classes of ships of some of the foreign navies (continued).

JULY. Battle of the velocities. Notes of lectures on artillery in coast defence—Fire control, Fire discipline.

This chapter includes illustrative tables showing at what points to attack certain classes of vessels, correction tables for tide, and a diagram giving penetrations of different English projectiles in wrought iron.

AUGUST. Fire discipline; its necessity in a battery of horse or field artillery, and the best means of securing it. (The Duncan gold medal prize essay for 1892.)

SEPTEMBER. Fire discipline. (The silver medal prize essay.)

OCTOBER. The U. S. Military Academy at West Point. Fire discipline. (Commended essay, 1892.) F. J. H.

REVISTA TECNOLÓGICO INDUSTRIAL.

APRIL, 1892. Resisting strength of materials.

A study of trials of iron and steel.

MAY. A floating derrick of 80 tons. Resistance of materials.

JUNE. A new phase in aluminium; its alloyage. The Munier multiple telegraph type writer.

A full description of the apparatus is given.

JULY. A new phase of the metal aluminium; its alloys, etc. (ended). Resistance of materials, etc. (continued). J. L.

REVUE MARITIME ET COLONIALE.

JUNE, 1892. A study of the mechanical theory of heat. Problems of the British Empire (continued). Progress made in artillery during the year 1890.

A very interesting article.

Long aërial voyages; air-balloons and exploration of the African continent.

JULY. Historical studies upon the military marine of France.

The article deals with the French navy before and during the Seven Years' War.

A study of the mechanical theory of heat. The English fleet off the coasts of Aunis and Saintonge in 1757. A vocabulary of powders and explosives (continued). Distribution of the small planets between Mars and Jupiter. Long aërial voyages, etc. (continued).

AUGUST. Origin of the French East India establishments. A vocabulary of powders and explosives (continued). The former marine corps of the French navy, 1622–1792.

SEPTEMBER. Statistics of shipwrecks and other maritime disasters for the year 1890. Origins of the French East India colonies; Ján Begum (Mme. Dupleix); 1706–1756. Historical studies of the military marine of France; the French navy before and during the Seven Years' War (continued). Long distance aërial voyages; aërostats and the exploration of the African continent. Naval chronicles.

OCTOBER. Among the Kanaks of New Caledonia. Long distance aërial voyages, etc. Origins of the French East India colonies, etc. (continued). Statistics of shipwrecks and other maritime disasters for the year 1890 (ended). Geometry of naval tactics; fourth series. A study of the mechanical theory of heat (continued).

J. L.

REVUE DU CERCLE MILITAIRE.

MAY 8, 1892. Works of the Geographical Service in France and Algeria, 1890–1891. The "lava" of the Cossacks.

Lava is an eastern expression representing a converging effort from circumference to centre and has no relation to volcanic lava. This peculiar mode of fighting of the Cossack is described at length through several numbers of the Revue and forms an interesting reading.

The use of the railways during the Turko-Russian war.

MAY 15. Works of the Geographical Service in France and Algeria during the years 1890–1891 (ended).

MAY 22. The different routes from the coast into the interior of Morocco. The English torpedo-boats.

JUNE 12. Projected formation of a reserve of Algerian "tirailleurs." The lines of penetration into the interior of Morocco (ended).

JUNE 19. The Royal Sovereign. A reserve of Algerian "tirailleurs."

JUNE 26. The Austro-Hungarian army regulations.

JULY 3. A study of Dahomey (with map). The English navy and Parliament. The fortifications of Switzerland.

JULY 10. The first engagements of the army of the Rhine (1890), from the personal notes of an officer.

Continued in several numbers of the Revue.

JULY 24. The Division ambulance.

AUG. 28. The new drill regulations for the German army. The division army ambulance. The pneumatic gun in the United States. The first engagements of the army of the Rhine (Franco-German War).

SEPTEMBER 4. The technical troops of the Austro-Hungarian army (engineer corps, pioneer and railway-telegraph regiments).

SEPTEMBER 11. The Dauteteau rifle, caliber 6.5 mm. The technical troops of the Austro-Hungarian army (continued). The Russian naval manœuvres of 1892.

SEPTEMBER 25 and OCTOBER 2. The Divisions of the reserve at the manœuvres of 1892. The Chinese army of the green standard.

J. L.

THE STEAMSHIP.

MAY, 1892. The action of the screw and hydraulic, or jet, propeller. A computation of Joule's equivalent. The Institution of Naval Architects (reviewed elsewhere).

JUNE. Captain Weir's azimuth diagram. The future of cast steel. The engines of the U. S. S. S. Monterey. Flexible metallic

tubing. The uses of asbestos in marine engineering. The first-class protected cruiser Gibraltar.

JULY. An improved steam engine governor. Air required for combustion. The new battleship Resolution. Forced blast oil-firing system.

AUGUST. Communication between stranded ships and the shore.

Illustrations and description of a rocket grapnel, to the inventors of which was awarded the prize offered by the London Graphic for the best means of establishing communication between stranded ships and the shore.

The question of lubrication. Indicator diagrams. Inclined triple expansion engines. The dimensions of modern warships. Pitting in boilers. The modern marine boiler. Petroleum steamers; their design and construction.

OCTOBER. Stockless anchors. Indicator diagrams. Corrugated furnaces. The treatment of marine boilers. Modern systems of refrigeration on ships. J. K. B.

TRANSACTIONS OF THE INSTITUTION OF NAVAL ARCHITECTS.

VOLUME XXXIII., 1892. Recent progress in warship construction, by Sir Nathaniel Barnaby. On the alterations in the types and proportions of mercantile vessels, together with recent improvements in their construction and depth of loading, as affecting their safety at sea, by B. Martell. Some notes on the history, progress and recent practice in marine engineering, by A. J. Durston. Progress in marine engineering in the mercantile marine, by A. E. Seaton. Summaries of the alterations and improvements in naval architecture and marine engineering in the English navy and merchant marine, as illustrated by the Naval Exhibition, the cause of this progress and the reasons for the survival of existing types. Center and wing ballast tank suctions in double-bottomed vessels, by G. R. Brace. On the weak points in steamers carrying oil in bulk, and the type which experience has shown to be most suitable for this trade, by George Eldredge. On divisional water-tight bulkheads, as applied to steamers and sailing vessels, by B. Martell. Notes on experiments with inflammable and explosive atmospheres of petroleum vapor, by J. H. Heck. Discussion of important subjects concerning the merchant marine. On steadying vessels at sea, by J. I. Thornycroft. On balancing marine engines, and the vibration of vessels, by A. F. Yarrow.

These well-known torpedo-boat builders, after stating the causes of rolling and vibration, explain their solutions of the different problems involved in overcoming these defects in small vessels. The former, with a short-period pendulum and a series of electro-magnets, automatically controls a hydraulic ram, which manœuvres a heavy weight athwartships, so that it moves downwards as the vessel inclines, thus reducing the right-

ing moment and the stability. The apparatus was tried in rough weather at various times on the yacht Cecile, and it was found that the angle of rolling was reduced from 18 degrees to 9 degrees. The author remarks that the half motion deducted from the rolling was much the worse half.

Mr. Yarrow shows that the true cause of vibration is due to the moving parts of the machinery; their momentum is accompanied by an equal momentum of the ship in an opposite direction. The correct method of overcoming the vibration is to design engines completely balanced in all directions during all phases of a revolution by the use of weights so situated that their momentum is at all times equal and opposite to that of the rotating, and particularly the reciprocating parts of the engine.

Notes on some recent experiences with H. M. ships, by W. H. White.

A summary o the official trials of the various types of the 70 English warships authorized in 1889, with discussions as to the effect of the depth of water on speed, vibrations at high speed and the advantages of using mild steel in hull construction, as illustrated by the mere local injuries caused by the grounding of the Victoria.

A ram vessel, and the importance of rams in war, by Commander E. B. Boyle, R. N.

Advocates the use of a double-ended ram having four rudders, with a screw at each extremity.

Whaleback steamers, by F. C. Goodall.

Discusses the advantages and disadvantages of this well-known type of American cargo carriers, and proposes certain improvements.

On an approximate rule for the vertical position of the centre of buoyancy, by S. W. F. Morrish.

Explains a rule which has previously been discovered by M. Normand, the famous French torpedo-boat builder.

Some notes on the strength of steamers, by A. Denny.

Presents a set of interesting tables showing variations of stresses in vessels of various forms under different conditions of loading.

On the transverse stability of ships, and a rapid method of determining it, by W. Hok.

Explains a new and rapid method for working out curves of stability.

On the theoretical effect of the race rotation on screw propeller efficiency, by R. E. Froude. On convenient curves for determining the most suitable dimensions for screw propellers, by R. E. Froude. On some additional features in the "Constant" notation used at the Admiralty Experimental Works, by R. E. Froude.

Short but valuable papers by the well-known experimentalist.

Performance of three sets of engines belonging to the second-class cruisers recently added to H. M. Navy, as calculated from the full power steam trials, by J. G. Liversidge.

An analysis to ascertain the causes of the varying efficiencies of different engines.

W. J. B.

TRANSACTIONS OF THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

VOLUME XLI., PART I. Experiments with explosives. Notes on the products and temperature of denotation of some high explosives.

PART II. Notes on an electric pumping plant. The practical transmission of power by electricity.

PART III. An inquiry into the cause of two colliery explosions.

PART IV. The detonation of high explosives by percussion. The iron ores of Spain. J. K. B.

LE YACHT.

JUNE 11, 1892. Remarks on the naval budget. The new battleships to be fitted with triple screws; the reason thereof. Review of the paper by Mr. Geo. Quick, of England, published in the U. S. Naval Institute Proceedings, concerning the increasing need for competent engineers on board men-of war. The cyclone of Mauritius; a relation by the commander of the Pei-Ho.

JUNE 25. Lord Brassey's Naval Annual. The torpedo-cruiser Wattignies.

JULY, 2. Trials of the Schneider rapid-firing gun of 15 cm. History of the gradual development of yachting. Vibrations of steam vessels.

JULY 30. Evolutions of the English fleet. Optic firing.

"This is a bright invention whose use has been recommended recently by a board of naval officers, and may be the prelude of a revolution in naval construction." The inventor, Commander de Fraisseix, of the French navy, has attempted to solve the problem of pointing heavy guns by using the principle of the photographer's camera. Stated briefly, his method of procedure was as follows: He inserted a lens in the place of the fore-sight, substituted for the back-sight a screen of white cloth, as being less fragile than the roughened glass of the photographer, and arranged a sort of camera by means of dark curtains of a flimsy fabric in such a manner that the image of the object of attack is cast on the screen, where the gunner watches it at his ease. A telemetric scale provides for the variation in position of the apparatus to accord with the distance of the object aimed at. The thing is extremely simple, and absolutely accurate, the gunner having the advantage of the extreme accuracy of the lens, which is of primary importance in firing at long range.

The optic sight was first tried in 1878, on board the school-ship Souverain. During, and since 1890, it has been repeatedly and successfully tried on the St. Louis, Duguesclin, Hoche, Courbet, and finally on the Achéron. At each trial the officers declared that the invention possessed mathematical precision, that it was simple and easy of manipulation, and did not require expert gunners, and was far superior to the ordinary way of pointing a gun.

The War Department has also experimented with it in the armored turrets of the advance works of fortified places. The commission in charge of the trial was not at first favorably disposed; but it stood the tests so successfully that a revulsion of sentiment in its favor took place, and it met with hearty approval.

In addition to the advantages already cited, this method of sighting possesses another of great importance. With it the gun-ports need be only sufficiently large to provide for the train of the gun, and thus additional protection to the crew may be gained. This consideration is of great importance in *any* case; and, in the case of turrets, might be a determining factor in deciding between open and closed turrets. After a six months' trial on board the Achéron, the board expressed the unanimous opinion that optic sighting should be adopted on all battleships fitted with closed turrets, and further recommended that measures be taken to provide all vessels in course of construction with closed turrets in anticipation of the installation of optic sights.

AUGUST 6. The French naval manœuvres. The aluminum yachts on the Lake of Zurich (with plates).

AUGUST 11. Aluminum construction, its probable developments and advantages.

"With the exception of three yachts at Zurich, one Swedish lifeboat, and a cutter in course of construction in England, we are not aware of any aluminum boats in existence. . . . It is certainly a remarkable fact that in three distinct places in Europe, far remote from one another, the same bold and somewhat hasty experiment has been made at the same time. In our opinion, this curious coincidence is not an exclusive proof of anxious desire for new inventions, but rather goes to show that the era of wood and iron in boat construction is passing away. . . . The cost of aluminum will gradually get lower and lower, owing as much to competition as to the general use of the metal in all kinds of industries; and inevitably, the advantages it presents in naval construction will by degrees make up, and more, for the extra outlay. These advantages are specially important from the triple point of view of lightness of hull, inalterability, and a great percentage of saving in the intrinsic value of the principal material. This saving is due to the remarkable simplicity and low cost of the metallurgy of aluminum, a simple re-melting restoring to it all its value. This is not so with ordinary constructions of wood or iron; hence the excess in the cost of aluminum shipbuilding is greatly diminished. It is, indeed, evident that if from the sum total expended on an aluminum vessel during its existence be deducted the value of the old material, that is, a great portion of the primitive material of the hull, the excess in the cost of the first purchase will be almost blotted out. The inalterability of the metal, which may be affirmed to be absolute, at least in regard to contact with air and fresh water, contributes also to a reduction in the cost, since it does away with paintings or coatings of all kinds, and allows of a great saving in the care and preservation of the vessel.

"The important point, in fact the reason for adopting aluminum in shipbuilding, is the extreme lightness of hull obtainable by the use of this metal. All navy people know full well the importance of reducing to a minimum the weight of the hull. In a vessel this weight is, so to speak, a dead weight, reducing in proportion the allotment for the engines, and diminishing the speed, coal endurance, and the mercantile or military worth of the ship. Now, in the small craft referred to as already built, the weight of the hulls is less than one-half and even two-fifths of the hulls of similar ones built of wood.

"Without insisting upon the good results likely to follow the introduction of the new metal in the construction of large vessels, which, in the present stage, might seem premature, it is nevertheless easy to demonstrate that the considerable reduction in the weight of hull affects many other small boats besides yachts. We will mention particularly the boats carried by large yachts and vessels-of-war and lifeboats. Boats in actual use—whaleboats and the like—are always too cumbrous. They burden the vessel,

not only with their own weights, but with the often more important ones of their hoisting apparatus, davits, winches, blocks, tackles, and all the fastenings they necessitate. Any decided diminution in the weight of such boats tends, therefore, towards a simplification of gear, and a corresponding decrease in the weight of their fixtures. In many cases the savings thus obtained would balance the extra costs of the boats.

"On the other hand, their tightness would not be impaired, as happens after a very short time with wooden boats, nor would they need the tedious care necessary to preserve sheet-iron boats from oxidation.

"Finally, a most important point: such boats could, with far more facility than ordinary boats, be fitted with air compartments, which would render them absolutely unsinkable. The latter advantage is of utmost importance in lifeboats." J. L.

AUGUST 20. The French naval manœuvres.

The theme prepared by the Admiralty for the Channel Squadron, embraced attacks upon the ports of Brest, Cherbourg and Havre. The most important point was to test the efficiency of the semaphoric service; the results were satisfactory.

AUGUST 27. The commercial naval schools: Report of the committee.

September 3. The coast defense sectors (apropos of the late naval manœuvres).

The coasts of France are divided into fifteen sectors. Two armored coast-guards and an indefinite number of torpedo-boats patrol each sector in case of war, or during mobilization in time of peace. In his article the author suggests changes tending to improve the service.

SEPTEMBER 10. Our armament of rapid-firing guns. The Dutemple boiler.

SEPTEMBER 17. The festivities in honor of Christopher Columbus. The Russian naval manœuvres.

SEPTEMBER 24. The Board of General Inspectors, and the High Council of the Navy. The U. S. Cruiser Columbia.

OCTOBER 6. The new organization of the naval reserve. The Russian manœuvres in the Black Sea. J. L.

EXCHANGES, BOOKS AND PERIODICALS RECEIVED.

AMERICAN CHEMICAL JOURNAL.

ANNUAL OF THE OFFICE OF NAVAL INTELLIGENCE, GEN. INF. SERIES, No. XI.

ANNUAL REPORT OF THE POSTMASTER-GENERAL.

ANNUAL STATISTICAL REPORT OF THE AMERICAN IRON AND STEEL ASSOCIATION.

BULLETIN OF THE AMERICAN GEOGRAPHICAL SOCIETY.

BULLETIN OF THE AMERICAN IRON AND STEEL ASSOCIATION.

COLLIERY ENGINEER.

ELECTRICAL REVIEW.

ELECTRICITY AND MAGNETISM, by Edwin J. Houston. The W. J. Johnson Co., New York.

ENGINEER, New York.

ENGINEER, London.

ENGINEERING.

ENGINEERING—MECHANICS.

ESSAYS OF THE DEPARTMENTS OF ARTILLERY AND MILITARY SCIENCE, U. S. Artillery School, Class of 1892.

HAND-BOOK OF THE U. S. S. PHILADELPHIA.

JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

JOURNAL OF THE FRANKLIN INSTITUTE.

JOURNAL AND PROCEEDINGS OF THE UNITED SERVICE INSTITUTION OF NEW SOUTH WALES.

LOS ORIJENES DE NUESTRA MARINA MILITAR, by Admiral Luis Uribe Orrego, of the Chilean Navy.

MAGNETIC OBSERVATIONS OF THE UNITED STATES NAVAL OBSERVATORY, 1891–1892.

METEOROLOGICAL OBSERVATIONS OF THE UNITED STATES NAVAL OBSERVATORY, 1883–1887, 1888.

MEMOIRES DE LA SOCIÉTÉ DES INGÉNIEURS CIVILS.

MINERAL RESOURCES OF THE UNITED STATES.

MODERN GUNS AND SMOKELESS POWDER, by Arthur Rigg and James Garvie. Spon & Chamberlain, New York.

NORSK TIDDSKRIFT FOR SOVAESEN.

OBSERVATIONS MADE DURING THE YEAR 1888 AT THE UNITED STATES NAVAL OBSERVATORY.

ONE HUNDRED AND FIFTIETH ANNIVERSARY OF THE FOUNDING OF THE FIRST CORPS OF CADETS, MASS. VOL. MILITIA.

PROCEEDINGS OF THE AMERICAN ACADEMY OF ARTS AND SCIENCES.

PROCEEDINGS OF THE AMERICAN PHILOSOPHICAL SOCIETY.

PROCEEDINGS OF THE INSTITUTION OF MECHANICAL ENGINEERS.

RAILROAD GAZETTE.

REPORT ON SOME OF THE MAGNETIC OBSERVATORIES OF EUROPE, by Ensign C. C. Marsh, U. S. N.

REPORT OF THE INDIANA ENGINEERING SOCIETY.

REVISTA MARITIMA BRAZILEIRA.

REVISTA MILITAR DE CHILE.

RIVISTA DI ARTIGLIERIA E GENIO.

RIVISTA MARITTIMA.

SCHOOL OF MINES QUARTERLY.

STEVENS INDICATOR.

TEKNISK TIDSKRIFT.

THÉORIE DU NAVIRE, by J. Pollard and A. Dudebout Gauthier. Villars et Fils, Paris.

TIDSKRIFT SJOVASENDET.

TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.

TRANSACTIONS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

TRANSACTIONS OF THE CANADIAN INSTITUTE.

TRANSACTIONS OF THE CANADIAN SOCIETY OF CIVIL ENGINEERS.

TRANSACTIONS OF THE INSTITUTION OF CIVIL ENGINEERS.
TRANSACTIONS OF THE NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIP-BUILDERS.
TRANSACTIONS OF THE TECHNICAL SOCIETY OF THE PACIFIC COAST.
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NAVAL INSTITUTE PRIZE ESSAY, 1894.

A prize of one hundred dollars, with a gold medal, is offered by the Naval Institute for the best essay presented on any subject pertaining to the naval profession, subject to the following rules:

1. The award for the Prize shall be made by the Board of Control, voting by ballot and without knowledge of the names of the competitors.

2. Each competitor to send his essay in a sealed envelope to the Secretary and Treasurer on or before January 1, 1894. The name of the writer shall not be given in this envelope, but instead thereof a motto. Accompanying the essay a separate sealed envelope will be sent to the Secretary and Treasurer, with the motto on the outside and writer's name and motto inside. This envelope is not to be opened until after the decision of the Board.

2. The successful essay to be published in the Proceedings of the Institute; and the essays of other competitors, receiving honorable mention, to be published also, at the discretion of the Board of Control; and no change shall be made in the text of any competitive essay, published in the Proceedings of the Institute, after it leaves the hands of the Board.

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5. The essay is limited to fifty (50) printed pages of the Proceedings of the Institute.

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8. In the event of the Prize being awarded to the winner of a previous year, a gold clasp, suitably engraved, will be given in lieu of a gold medal.

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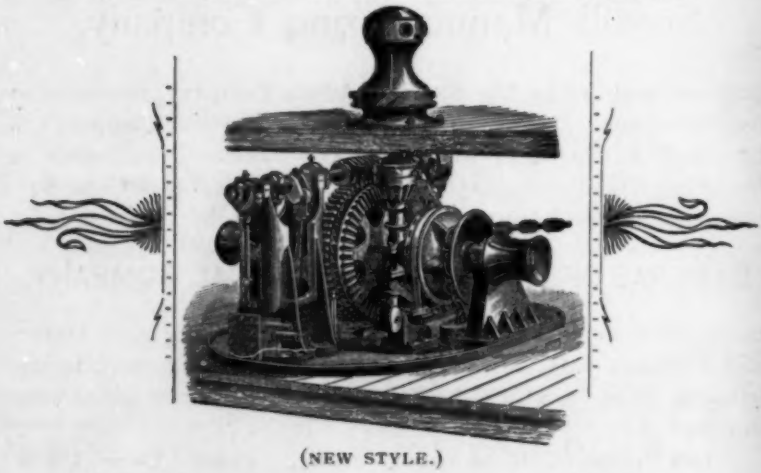

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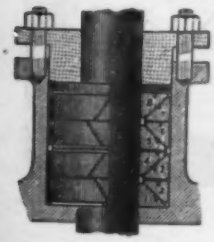

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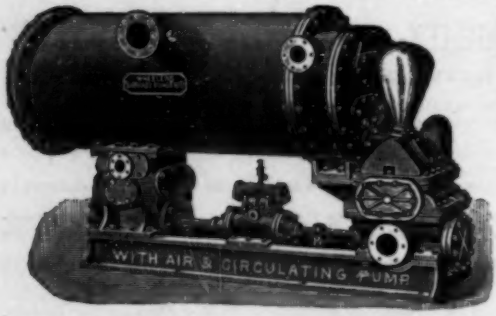

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